SEN R.N. (1.982)

Physiological adaptation of people & in tropical countries in some of their anthropometric dimensions in relation with thermoregulation
from BASU A., MALHOTRA K.C
HUMAN GENETICS AND ADAPTATION Vol 2 p 149, 156

From the correct observation that for small and light people the body surface calculation formula doesn't work well, he suggest another formula

$$W_{Kg}^{0,5664} \times H_{cm}^{0,3008} \times 377,82$$ instead of

[illegible] of DUBOIS and DU BOIS (1.916)

$$W_{Kg}^{0,425} \times H_{cm}^{0,725} \times 71.84$$

This is ~~[illegible]~~ - perhaps - acceptable. What is not are his usual philosophical considerations about Indians as different, "Indians in general living in tropical countries have relatively greater surface area of the body than the westerners living in cold climate have"

What has to be said about the poor portuguese farmer small and light and the rich Bombay middle class youngsters which are Tall and heavy !!!..

No people are not different.

W

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Physiological Adaptation of People in Tropical Countries in Some of their Anthropometric Dimensions in Relation to Thermoregulation

RABINDRA NATH SEN

ABSTRACT The metabolic rate of the human body is usually expressed per unit of body surface area, which depends on the various body dimensions. As the surface area relates to heat loss it changes with the environmental temperature, not only by developing efficient heat conserving and heat dissipating devices but also by rolling up in cold weather and spreading out in hot weather.

The study on determination of the surface area of the body of Indians confirm that Indians, in general, have relatively greater surface area of the body than the Westerners living in cold climates have. Our observations that in addition to the increase of surface area the Indians, in general, have comparatively lower body weight and lower body fat are in line with the Climatic Rules of Bergmann and Allen.

Based on actual determination of body surface area of 31 Indians the following prediction equation, where the exponents of weight (W) and height (H) were so chosen as to satisfy that the expression remained bidimensional was suggested: $A\ (cm^2) = W(kg)^{0.5664} \times H(cm)^{0.3008} \times 377.82$. The significance of the observations that body surface area as determined by the above weight-height formula is relatively higher in Indians than in Westerners, and that the higher power of weight in the above formula compared to that obtained by Du Bois and Du Bois (1916) suggests that the amount of change in the surface area of Indians for unit change in weight is higher than that for unit change in height, is discussed.

The basal metabolic rate of the human body is usually expressed per unit of body surface area which depends on the various body dimensions.

It is believed by some that the rate of cooling of a body is proportional to its surface area. If so, the heat production must likewise be proportional to the surface area since in homeotherms (assuming constancy of body temperature) heat production must equal heat loss. Homeotherms, therefore, must have developed in course of evolution a heat production control system to function in relation to surface area. As heat production is proportional to oxygen consumption and since heat loss and heat production are proportional to free surface and since surfaces vary with the squares of the homologous sides it follows that oxygen consumption, heat production and heat loss are proportional to the square of the corresponding dimensions of the animals under comparison.

From the theory of similitude surface area varies with the square of the linear size, provided the large and small animals are similar in the way that large and small circles or spheres are similar. Since strict biological similitude between animals in space and time is impossible strict agreement between observed facts on animals and deductions by dimensional analysis are impossible—only approximations can be made. It is generally believed that in considering the constancy of basal heat production per square meter of body surface there should be no confusion caused by linking this observation with that of a cooling body. If only a question of cooling were involved metabolism would have ceased to exist in warm climates and the cells would have died.

Whatever may be the theoretical significance of body surface as a biometric unit for reference of metabolic measurements it seems presently that the use of such a unit gives less variable results for individuals differing greatly in size and for different species. The fact that the external surface area per unit weight declines with increasing weight probably explains from the evolutionary viewpoint the observation that the basal metabolism per unit weight declines with increasing body weight. The basal metabolic rate is expressed generally in terms of kilocalories per hour per square meter of body surface and clinically as percentage below or above a normal standard.

The methods of determining the metabolic rate have been greatly improved leaving the surface area as the doubtful factor. The surface area may be calculated by using different formulae proposed by different workers. The number of formulae for the determination of surface area is large but the number of individuals whose surface areas have been measured is small. It has been pointed out that it is absurd to measure the metabolic rate or heat production with an error of approximately 2 per cent and then express the metabolism in terms of units of surface area which is estimated by a formula that may be inaccurate to the extent of 10 to 30 per cent.

Leutulle and Pompilian (1906) used a method of determining surface area somewhat similar to the linear formula adopted by Du Bois and Du Bois (1915) nine years later. They consider that the surface of the body consists of the surface of a number of trapezoids, one covering the upper arm, one the forearm, one the hand, one for each finger, and so on. They calculated the area of each trapezoid from the length of the part and the circumference at the two borders which form the sides of the figures. Lassabliere (1910) measured the surface of a number of children by marking out the skin in geometrical patterns and determining the area by means of a planimeter.

In 1915 Du Bois and Du Bois repeated Meeh's (1879) work of determination of the surface area of the body. After much experimentation they devised some improvements on the methods previously used.

The subjects of Du Bois and Du Bois (1915) consisted of one cretin, one convalescent typhoid patient, one tall thin man, one tall man of average build, one very short and fat woman, one tall emacited diabetic patient, one fatty body, one dead body, one sculptor's model and one very tall and thin man.

MATERIALS AND METHODS

In the present investigation the data on surface area of the body of 15 Indian adult males (Sen, 1954; Banerjee and Sen, 1955), 7 Indian adult females (Sen, 1960; Banerjee and Sen, 1958; Banerjee et al., 1958) and 9 Indian children (Sen, 1960, 1967) actually determined by a combination of the tape, the surface integrator and the plaster mould methods have been considered.

The method of least squares was employed to estimate the values of the exponents of weight and height and also of the constant, C, in the formula, A (sq cm) $= W^{\alpha}_{(kg)} \times H^{\beta}_{(cm)} \times C$. A new prediction equation, $A = W^{0.5664} \times H^{0.3008} \times 377{\cdot}82$, was obtained from the data of 31 subjects (adult males, females and children) when the restriction, $3\alpha + \beta = 2$, was imposed to satisfy that both sides of the above equation remained bidimensional. When no restrictions were used another new prediction equation, $A = W^{0.5707} \times H^{0.2957} \times 381{\cdot}71$, was obtained. It was observed that the restriction increased the standard error of estimate by only 0·29 per cent on the positive side and 0·27 per cent on the negative side. The increase in the standard error of estimate is not significant at 1 per cent level.

RESULTS AND DISCUSSION

It was observed by Takeya (1929) and others including the present author (Sen, 1954; Banerjee and Sen, 1958) that the corrected constant in the weight-height formula of Du Bois and Du Bois (1916) generally becomes smaller with increase of height. There is such a tendency also in the case of Indian adult males, females and children. The comparative values are presented in Table 1.

As the average height of Indians (especially the Bengalis) is much below the average height of Americans the higher value of the new constant, 74·66, 78·28, 76·61 in the case of Indian adult males, adult females and children, respectively may be explained in terms of the above observation. The best results for Japanese men were obtained by using the weight-height formula with the constant 72·46 instead of 71·84.

Takeya (1929) measuring 22 Japanese by a slightly different method concluded that the best formula to calculate the surface area was the weight-height formula with a constant of 75·05 instead of 71·84. He also noted that the constant seems to vary with the height in so far as when the height increases the constant decreases.

Stevenson (1928) measured the surface of 10 Chinese using both the "linear" and "weight-height" formulae. The totals obtained by adding the surfaces of different parts according to the linear formulae agreed closely with the results calculated according to the weight-height formula but this he thought was due to a fortuitous compensation between errors in different regions. Stevenson (1930) has suggested a new set of constants for the linear formula when applied to the Chinese. The weight-height formula gives higher values than the linear formulae with the Chinese.

TABLE 1. A comparison of different formulae for the calculation of body surface area (A cm²) from the body weight (W kg) and body height (H cm)

Sl. No.	Formulae for surface area	No. of subjects with reference
1.	$A = W^{0.425} \times H^{0.725} \times 71{\cdot}84$	10 Americans (Du Bois and Du Bois, 1916)
2.	$A = W^{0.425} \times H^{0.725} \times 75{\cdot}05$	22 Japanese (Takeya, 1929)
3.	$A = W^{0.425} \times H^{0.725} \times 72{\cdot}46$	10 Japanese (Takahira, 1925)
4.	$A = W^{0.425} \times H^{0.725} \times 74{\cdot}40$	12 German infants (Pfaundler, 1916a and 1916b)
5.	$A = W^{0.425} \times H^{0.725} \times 78{\cdot}50$	Infants (Faber and Melcher, 1921)
6.	$A = W^{0.425} \times H^{0.725} \times 76{\cdot}40$	135 Subjects in literature (Boyd et al., 1930)
7.	$A = W^{0.425} \times H^{0.725} \times 74{\cdot}66$	15 Indian adult males (Sen, 1954; Banerjee and Sen, 1955, 1957)
8.	$A = W^{0.425} \times H^{0.725} \times 78{\cdot}28$	7 Indian adult females (Sen, 1960; Banerjee et al., 1958)
9.	$A = W^{0.425} \times H^{0.725} \times 76{\cdot}61$	9 Indian children (Sen, 1960, 1967)
10.	$A = W^{0.425} \times H^{0.725} \times 76{\cdot}04$	31 Indian subjects (Sen, 1960, 1967)
11.	$A = W^{0.427} \times H^{0.718} \times 74{\cdot}49$	10 Japanese (Takahira, 1925)
12.	$A = W^{0.575} \times H^{0.275} \times 394{\cdot}56$	135 Subjects in literature (Boyd et al., 1930)
13.	$A = W^{0.533} \times H^{0.400} \times 241{\cdot}10$	133 Subjects in literature (Boyd et al., 1930)
14.	$A = W^{0.5664} \times H^{0.3008} \times 377{\cdot}82$	31 Indian subjects (Sen, 1960, 1967)
15.	$A = W^{0.5107} \times H^{0.2957} \times 381{\cdot}71$	31 Indian subjects (Sen, 1960, 1967)

The surface area of the body of 15 Indian adult males actually measured by a combination of different methods was on the average 3·66 per cent higher than the surface area calculated from the weight-height formula of DuBois and Du Bois (1916). The nude body weights of the subjects varied from 36·51 kg to 66·79 kg and the height varied from 151·9 cm to 178·1 cm. A formula, $A = W^{0.425} \times H^{0.725} \times 74{\cdot}66$, was suggested for the determination of the surface area of the body of Indian adult males. Sen (1954) also measured the surface area by the linear formula of Du Bois and Du Bois (1916) and found that the linear formula was not very useful for estimating the surface areas of different parts of the body in case of Indian adult males. Different constants for the linear formulae for different parts of the body obtained from the actual measurements of the body were also suggested (Sen, 1954; Banerjee and Sen, 1955; Sen, 1960).

Faber and Melcher (1921) using the linear standards suggested that for infants a constant of 78·50 be used for the weight-height formula.

The work of Boyd (1935) and Klein and Scammon (1930) are, perhaps, the best on small children. Taking these as a basis and adding the series of 135 measurements (mostly composed of small children) that are found in the literature they determined the mean relative deviations of various formulae (Boyd et al., 1930). The weight-height formula of Du Bois and Du Bois (1916) showed a mean relative deviation of 7·30 per cent for the whole series. Using 76·40 as the constant the results were a little better.

The weight-height formula of Du Bois and Du Bois (1916) gave results which were on the average 8·10 per cent lower in the case of Indian adult females and 6·10 per cent lower in the case of Indian children. The percentage error varied between —1·80 to —12·00 in the case of adult females and it varied between —2·40 to —11·90 in the case of children. The corrected constants in the new weight-height formula were 74·66, 78·28, 76·61 in the case of adult males, females and children, respectively.

The low results obtained with the weight-height formula of Du Bois and Du Bois (1916) may be explained by the fact that the average Indian subjects, especially the Bengali, are more slim than the Americans. The weight-height formula of Du Bois and Du Bois (1916) gives usually low results with emaciated subjects, i.e., the corrected constant becomes generally higher in the emaciated subjects and also in the children.

The higher value of the constant in the case of Indian adult females than in the case of Indian adult males seems to be due to the lower average height in proportion to the weight of the body in the former than in the latter.

It may also be due to the adaptation of the body of the females in the tropics to provide for more surface for evaporation needed to help heat dissipation which is hindered by the greater proportion of fat present in the body of adult females than in that of adult males. It is interesting to note that in most of the subjects the correct constants were higher in those having greater percentage of body fat. Van Gran and Wyndham (1964) also observed that the weight-height formula of Du Bois and Du Bois (1916) underestimates the true surface area in the case of their subjects in hot climates, which observation is similar to ours.

So far, we were considering the constant in the weight-height formula of Du Bois and Du Bois (1916) with the assumption that the exponents of weight and height were the same as found by Du Bois and Du Bois (1916). In order to obtain the best possible values of the exponents and also the best fitted constant in the formula the least square method was used with the condition, $3\alpha+\beta = 2$, so that the expression, $A = W^{\alpha} \times H^{\beta} \times C$, remained bidimensional. The higher power of weight in the formula obtained in contrast to that obtained by Du Bois and Du Bois (1916) suggested that the amount of change in the surface area of Indians for unit change in weight is higher than that for the unit change in height.

The reason why a consideration of the height did not improve the calculations based on weight became apparent when the circumference of the body at various levels was considered. For instance, an increase of length above the knee would result in a greater increase of surface area than the same amount of increase of length below the knee. It was due to the fact that the average circumference of the thigh is greater than that of the legs. Again, variations in length and circumference of arms and hands would not affect the height at all. As the body weight was given less importance in the weight-height formula of Du Bois and Du Bois (1916) small variations in weight were thought to be of little significance to surface area. Stevenson (1928) also found in 10 Chinese subjects an increase in the constants for the upper extremities and a decrease in the constant for the trunk in the linear formulae.

Our observation conforms with the Climatic Rules of Bergmann and Allen. According to these rules there is a tendency of reduction in the surface area relative to weight in cold climates. Thus, many animals in the arctic region tend towards large globular wooly balls with the least possible area of the extremities such as ears, tails, snouts and legs. On the other hand in the tropics or under conditions of high temperature the animals tend towards smaller skinny forms with enlargement of the peripheral parts or extremities; thus, they usually have long legs, snouts, ears and tails. The surface area of Indian cows was found to be about 12 per cent greater than that of the European cows (Kibler and Brody, 1950).

It is very likely that the body form of people in the tropics would follow the same rules as in the case of animals. The main sources of the body's heat are the muscular tissues (particularly of the extremities) and the liver wherein numerous chemical reactions are carried out. Therefore, with an increase in the length of the extremities and decrease in the length or breadth of the trunk (small chest size) causing decrease in the body weight (including the weight of liver, cell solids—Banerjee and Sen, 1958) the surface area relative to weight of the body is increased in order to provide greater surface for evaporation in tropical climate to maintain the body temperature.

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SEN R.N., RAY G.G., NAG P.K. (1976)

Relationship between segmental and whole body weights of some indian subjects

PROCEEDINGS INTERNATIONAL ~~Book~~ COMMITTEE FOR PHYSICAL FITNESS RESEARCH ch 37, p 384 – 391

5 Indian cadavers had 59.4 % of body weight for trunk (that is higher than for "westerners") 32.4 % for limbs (lower).

For SEN, it mean that indians are different (racially? but what is indian race?). For me they are only underfed ~~and~~, underdevelopped, small that means that limbs are relatively small in relation with trunk.

The heights of the subjects are not given!

SEE RAY, SEN, NAG, BASU 81

Chapter 37

RELATIONSHIP BETWEEN SEGMENTAL AND WHOLE BODY WEIGHTS OF SOME INDIAN SUBJECTS*

R. N. Sen, G. G. Ray, and P. K. Nag

Abstract

Information regarding relationships between segmental and whole body weights, volumes, and centers of mass is important in biomechanics, sports, and industrial technology. For the present report, five Indian adult male cadavers were weighed by a servoindicator. The whole body was dissected into fourteen segments, severing each of the primary joints across its approximate center of rotation and weighing the resultant segment on a baby-weighing platform balance. The segmental volume (water displacement technique) and the center of mass (plumb-line technique) were also determined. The relative weight of the limbs (total arm 4.3 percent and total leg 12.9 percent of body weight) were much lower in Indians than values reported for Western and Japanese subjects. On the other hand, the relative weight of the trunk (58.2 percent) was much higher in Indian cadavers. The segmental volumes of the trunk and the limbs represent 59.4 and 32.4 percent of the total body volume respectively. The center of mass of the upper arm and of the thigh both lie some 48.9 percent of the total segmental length from the proximal end of the part. Simple regression equations are derived for the prediction of segmental weights; these may be used at least until further cadavers have been studied.

INDIAN PEOPLE DIFFER from Westerners with respect to body weight, body height and other dimensions, body surface area,

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basal metabolic rate, physical fitness, efficiency, and working capacity. Predictions of weight, volume, and center of mass for individual body segments are useful when analyzing biomechanical aspects of both sports and other activities including industrial work. However, no information on such variables has yet been reported for the Indian population. The present report thus describes a direct determination of segmental body composition in Indian cadavers. Comparative data for Western populations have been reported by Borelli,[2] the Weber brothers,[12] Harless,[9] Braune and Fischer[3] Dempster,[5] Williams and Lissner,[13] and Clauser et al.,[4] while information on the Japanese population has been presented by Mori and Yamamoto[10] and Fujikawa.[8]

Methods

Five unclaimed Indian adult male cadavers were selected for the present study, which was made during the cooler months of January and February. The selection of the cadavers was based on such considerations as the date of death, nutritional status, and the absence of wasting or debilitating disease. The sample was with one exception somewhat undernourished, and bodies had been preserved for approximately twenty-four hours in the hospital morgue.

After selection, the cadavers were placed inside a polythene bag, to avoid collection or evaporation of moisture. The experimental procedures were undertaken during the night, when the average room temperature was about 22°C. Each body was cleaned and swabbed with a solution containing equal proportions of phenol, glycerine, and water. The whole body weight was recorded with the help of a sensitive (± 0.05 kg) servoindicator calibrated by standard weights. Dissection of the various body segments used a method similar to that of Braune and Fischer[3] and Dempster.[5] Parts were severed at each of the primary joints, about the approximate center of rotation. Localized freezing during dissection was unfortunately impracticable. The joints severed were as follows:

HIP JOINT: The leg was abducted by about 30°. The plane of segmentation passed across the groin from the lower level of the iliac crest along the external shaft of the ilium, cutting the rim of the acetabulum across the ball and socket joint to sever the ischial tuberosity.

KNEE JOINT: The knee joint was bissected in an extended position. The plane of separation began near the lower part of the patella and bissected the maximum protrusion of the medial and lateral epicondyles of the femur. The patella was included with the lower leg.

ANKLE JOINT: The feet were plantar extended. The line of cutting began at the anterior superior edge of the neck of the talus and passed across the superior edge of the calcaneum.

SHOULDER JOINT: The shaft of the humerus was rotated laterally by about 15° to ensure that the cut passed from the tip of the acromion to the anatomical neck of the humerus and into the axilla without touching the shaft of the humerus or the medial surface of the upper arm.

ELBOW JOINT: Separation was begun by bissecting the olecranon process, crossing the greatest projection of the medial epicondyles of the humerus to end at the skin crease on the superior aspect of the elbow.

WRIST JOINT: The line of severance passed through the palpable groove between the lunate and capitate bones, bissecting the volar surface of the pisiform to end at the wrist crease.

NECK JOINT: The trunk was beheaded along the neck-chin intersection, commencing just above the hyoid bone and proceeding between the second and third cervical vertebrae.

In total, the body was thus dissected into fourteen segments. As soon as each segment had been detached from the body it was weighed on a calibrated baby-weighing platform balance. The beheaded trunk was reweighed with the servoindicator.

The center of mass of each limb segment was obtained by the plumb-line technique,[4] while volumes were determined by water displacement.

Results and Discussion

The cadavers included in the present study were of lower economic status. With one exception they were suffering from undernutrition. Their average age was 49 years. The average body weight was 37.3 kg, much lower than the fiftieth percentile value (45.9 kg)[11] for the Indian population.

The total arm and the total leg (including the thigh) represented an average of 4.3 and 12.9 percent of body weight respectively (Table 37-I). The weights of both limbs were relatively lower in Indian cadavers than in Westerners, a possible advantage in rapid unloaded movements in sports or assembly work. In consequence, the trunk (58.2 percent of body weight) was relatively heavier than in Western and Japanese studies. The relative values for individual limb segments (forearm, palm, total right leg and lower leg) are similar to those found in Japanese cadavers.[10] The relative weight of the head was similar to the values reported by Fujikawa[8] and Fischer.[7] The weight of the right arm of the Indians was greater than that of the left, but the weights of both legs were almost equal.

The sum of percentages for all segments was 94.4 percent, rather than 100 percent, the discrepancy reflecting loss of fluid and tissue during segmentation. The weight of the fluid and tissue collected during segmentation was thus added to the segmental weights in equal proportions to give the corrected values of Table 37-I. Dempster[5] and Clauser et al.[4] noted 6.4 and 1.4 percent loss of body weight respectively during dissection. The smaller losses of Clauser et al. were possibly due to use of the dry ice localized cooling technique.

The mean total body volume was 33.86 liters (Table 37-II). The volume of the trunk was 20.07 liters (59.39 percent of body volume), while that of the limbs (total arm and total leg, including thigh) represented only 32.4 percent of the body volume. Relative to Western studies,[6] the percentile distribution of most segmental volumes except the hands and feet were lower for the Indians.

Segmental centers of mass (right upper arm, forearm, thigh, and calf) could be determined in only two cadavers (Table 37-III). Centers for the upper arm and thigh both lay at some 48.9 percent of the total length from the proximal end of the segment, much as reported by Dempster.[5]

Simple linear regression equations for the prediction of

TABLE 37-I
AVERAGE WEIGHTS OF BODY SEGMENTS EXPRESSED AS PERCENTAGES OF TOTAL BODY WEIGHT.

Cadaver	*Sen, Ray, and Nag (1976)*	*Clauser et al. (1969)*	*Fujikawa (1963)*	*Mori and Yamamoto (1959)*	*Dempster (1955)*	*Fischer (1906)*	*Braune and Fischer (1889)*	*Harless (1860)*
Sample Size (n)	5	13	6	6	8	1	3	2
Segments:								
Head	9.0	7.3	8.2	11.7	7.1	8.8	6.9	7.6
Trunk	58.2	50.7	53.6	53.5	45.4	45.2	46.1	44.2
Total Right Arm	4.3	4.9	4.8	4.7	4.9	5.4	6.3	5.8
Upper arm	2.1	2.6	2.6	2.7	2.7	2.8	3.3	3.2
Forearm & Palm	2.2	2.3	2.2	2.0	2.2	2.5	3.0	2.6
Forearm	1.4	1.6	1.4	1.3	1.6	—	2.1	1.8
Palm	0.8	0.7	0.8	0.6	0.6	—	0.9	0.8
Total Left Arm	3.9	4.9	4.6	4.6	4.8	5.6	6.1	5.4
Total Right Leg including								
Thigh	12.2	16.1	14.4	12.6	15.7	17.8	17.3	18.5
Thigh	6.8	10.3	9.4	7.2	9.6	11.0	10.7	11.9
Leg and Foot	5.4	5.8	5.0	5.1	6.0	6.8	6.5	6.5
Leg	3.5	4.3	3.3	3.5	4.5	4.7	4.8	4.6
Foot	1.9	1.5	1.7	1.6	1.4	2.1	1.7	1.9
Total Left Leg including								
Thigh	12.2	16.1	14.5	12.6	15.7	17.3	17.3	19.3
Total	100.0	100.0	100.1	9.7	93.6	100.1	100.0	100.8

TABLE 37-II
AVERAGE SEGMENTAL VOLUMES, EXPRESSED AS PERCENTAGES OF WHOLE BODY VOLUME.

Segments	*Sen et al. (1976)* $n = 5$ Mean (l.)	% of TB	*Drillis and Contini (1966)* $n = 12$ Mean (l.)	% of TB
Total Body (TB)	33.855	100.00	—	100.00
Head	2.775	8.226	—	—
Neck & Trunk	20.071	59.395	—	—
Total Arm	2.933	8.630	3.971	5.730
Upper Arm	0.731*	2.158*	2.412	3.495
Forearm & Hand	0.763*	2.255*	—	—
Forearm	0.489*	1.455*	1.175	1.702
Hand	0.271*	0.800*	0.384	0.566
Total Leg	8.078	23.810	10.091	14.620
Thigh	2.133*	6.299*	6.378	9.241
Calf & Foot	1.861*	5.496*	—	—
Calf	1.173*	3.464*	2.818	4.083
Foot	0.688*	2.023*	0.895	1.297

*Values for right side of the body only.

TABLE 37-III
RATIO OF CENTER OF MASS OF SEGMENT LENGTH.

Source	*This Study Sen et al. 1976*	*Clauser et al. 1969*	*Dempster 1955*	*Fischer 1889*	*Braune and Fischer 1889*	*Harless 1860*
Total Body		41.2%				41.4%
Head		46.6	43.3%			36.2%
Trunk		38.0*				44.8
Total Arm		41.3		44.6%		
Upper Arm	48.9%	51.3	43.6	45.0	47.0	
Forearm & Hand		62.6*	67.7*	46.2	47.2	
Forearm	44.0	39.0	43.0		42.1	42.0
Hand		18.0*	49.4			39.7
Total Leg		38.2*	43.3	41.2		
Thigh	48.9	37.2*	43.3	43.6	44.0	48.9
Calf & Foot		47.5	43.7	53.7	52.4	
Calf	42.3	37.1	43.3	43.3	42.0	43.3
Foot		44.9	42.9		44.4	44.4

*These values are not directly comparable due to variations in the definition of segment length used by the different investigators.

TABLE 37-IV
REGRESSION EQUATIONS FOR PREDICTING SEGMENTAL WEIGHTS (Kg) FROM WHOLE BODY WEIGHT (INDIAN SUBJECTS)

Weight of Head	= 0.04 × Body Wt. + 1.47 ± 0.22*
Weight of Trunk	= 0.63 × Body Wt. − 2.88 ± 0.54
Weight of Total Right Arm	= 0.06 × Body Wt. − 0.67 ± 0.15
Weight of Right Upper Arm	= 0.03 × Body Wt. − 0.48 ± 0.06
Weight of Right Forearm	= 0.03 × Body Wt. − 0.43 ± 0.06
Weight of Right Palm	= 0.02 × Body Wt. − 0.26 ± 0.05
Weight of Total Left Arm	= 0.05 × Body Wt. − 0.31 ± 0.11
Weight of Total Right Leg Including Thigh	= 0.14 × Body Wt. − 1.0 ± 0.23
Weight of Right Thigh	= 0.09 × Body Wt. − 1.0 ± 0.21
Weight of Right Calf	= 0.03 × Body Wt. 0.0 ± 0.06
Weight of Right Foot	= 0.02 × Body Wt. − 0.01 ± 0.09
Weight of Total Left Leg including Thigh	= 0.14 × Body Wt. − 0.67 ± 0.20

*Standard Error of Estimate.

segmental weights from the whole body weight are given in Table 37-IV. The total number of cadavers studied was very small, as in other studies,[1, 4] but the equations developed may be useful at least for the people of eastern India until a larger sample has been studied.

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SEN R.N., GANGULI A.K., RAY G.G., DE A., CHAKRABARTI D. (1981)

Ergonomics study of tea leaf plucking operations : Criteria for selection and categorisation

APPLIED ERGONOMICS 12 2 83. 85

It is not a good paper

Scientifically, I ~~tha~~ dont think that the method is good : mixture of Time and Motion and $\dot{V}O_2$ max. I have not seen the basic idea.

Socially it is selection and not ergonomics.

We have to be careful about the field studies of SEN

Wisner's remarks

about Kogi's documents

June 86

Applied Ergonomics 1981, 12.2, 83–85

Ergonomics study of tea-leaf plucking operations: Criteria for selection and categorisation

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This paper describes a new method for the categorisation of female tea-leaf pluckers on the basis of quantity and quality of production, skill and efficiency. Subjects participating in a study on the ergonomics of tea-leaf plucking operations were so categorised, and the results have been compared with the existing groupings followed by the Tea-estate authorities. Such a method could facilitate predictive selection of pluckers, selection for training, and formation of groups in future studies.

A study of tea-plucking operations was proposed by the Tea Research Association, Assam, India, with a view to gathering information about the physiological status of the female pluckers and the ergonomics aspects of the plucking operation (Sen *et al*, 1979). Subjects were chosen from the volunteers among the normal female employees of the tea estate. Sub-groups were formed within the experimental group on the basis of records of average daily output supplied by the Tea-estate authorities. The sub-groups were designated 'fast', 'average' and 'slow' plucker categories. However, examination of the data furnished revealed that the boundaries of all the groups so formed overlap. Furthermore, while collating the data collected it was seen that some of the subjects exhibited characteristics similar to those of other groups and hence obviously did not belong to the groups to which they had been assigned. In the light of these considerations, an attempt was made to formulate a new system of categorisation.

Methods

In the course of the study, oxygen consumption during plucking operations was measured by Beckmann portable oxygen analyser (cross-checked in a few cases by collection of expired air over mercury in modified Bailey's bottles and subsequent analysis in a Scholander's apparatus.) Pulmonary ventilation (inspired air volume) was measured by a Wright's respirometer. Energy expenditure was calculated from the above according to the method of Consolazio *et al* (1963).

In addition to the gross energy costs so obtained, a productivity linked value (energy expended to pluck each shoot) was calculated from the gross energy costs and the number of shoots plucked (described below). This indicated the efficiency of each worker.

Time and motion studies were conducted simultaneously in order to establish different parameters and ratios as follows:

(1) *Average number of shoots plucked:* Since the number of shoots plucked in each cycle is not constant, the cycle time (Observed Time) cannot give a clear picture of the productivity of each subject. Hence, the average number of shoots plucked per minute was calculated from physical counts of the shoots plucked in a given time.

(2) *Average weight of shoots plucked:* This is the quotient of the weight of the shoots upon the number of shoots, and is influenced by the quantity of undesired vegetation plucked along with the required 'two leaves and a bud' in each shoot and thereby indicates the quality of the work performed.

(3) *Number of hand movements:* The number of movements of the left and right hands was measured by tally counters against time. Combined, these values gave the *Total numbers of hand movements.*

(4) *Ratio of number of shoots plucked to number of hand movements:* This ratio was obtained from the physical count of the number of shoots plucked and the count of the total numbers of hand movements (described above). This ratio offers an insight into the number of shoots plucked in a single grasp-disassemble movement and the number of wasteful movements made.

Results and discussion

The energy expenditure, time study and productivity of the female tea-pluckers are presented in Table 1.

Table 1: Energy expenditure, time study and productivity of female tea-pluckers

Subject number	Energy expenditure (kJ/min)	Average number of shoots plucked per min	Total number of hand movements per min	Average weight per shoot (g)	Number of shoots plucked/ number of hand movements	Energy expended to pluck one shoot (J/shoot)
4	18·29	114·7	142·0	1·19	0·81	159·5
7	13·98	128·4	118·8	0·75	1·08	108·9
8	12·10	104·9	99·1	0·94	1·06	115·3
9	13·81	100·2	101·1	1·06	0·99	137·8
10	7·70	77·6	86·7	1·06	0·90	99·2
11	13·86	123·5	133·1	1·79	0·93	112·2
12	11·85	131·8	84·1	1·06	1·57	89·9
13	8·20	92·5	104·1	0·69	0·89	88·7
15	25·87	189·3	172·1	0·98	1·10	136·7
16	9·96	66·1	108·8	1·24	0·61	150·7

As a preliminary basis for categorisation, four parameters were chosen from those recorded during the study. These were:

(1) average number of shoots plucked
(2) average weight of shoots plucked
(3) ratio of shoots plucked to hand movements, and
(4) energy expended to pluck each shoot,

being indicative of the quantity of production, quality of production, degree of skill, and efficiency (respectively). The heart-rate response was not selected since it is a very sensitive parameter and might give misleading values in the case of the small sample groups and because it was not possible to allow for psychological and thermal effects. Demarcation lines were set up for each of these four parameters.

The criteria for categorisation of female tea-pluckers are presented in Table 2.

Table 2: Criteria for categorisation of female tea-pluckers

Average number of shoots plucked per min	Average weight per shoot (g)	Ratio of shoots plucked to number of hand movements	Energy expended to pluck one shoot (J/shoot)	Points scored
140	<1·0	1·0	<150	3
75–140	1·0–1·15	0·7–1·0	150–200	2
<75	1·15	<0·7	200	1

Each subject was classified according to these parameters, and accordingly rated on the three-point scale. The total of the points obtained by each subject was then used to make the final categorisation, as follows:

Category 'A' : 11 points and above
Category 'B' : 10 points

Table 3: Categorisation of female tea-pluckers

Subject number	Points scored from: Average no of shoots per min	Average weight per shoot	Ratio of shoots plucked to movements	Energy expended per shoot	Total points	Suggested categorisation	Existing categorisation
7	2	3	3	3	11	A	Fast
8	2	3	3	3	11	A	Fast
15	3	3	3	3	12	A	Fast
12	2	2	3	3	10	B	Slow
13	2	3	2	3	10	B	Slow
9	2	2	2	3	9	C	Average
10	2	2	2	3	9	C	Slow
4	2	1	2	2	7	D	Average
11	2	1	2	3	8	D	Slow
16	1	1	1	2	5	D	Average

Category 'C' : 9 points
Category 'D' : 8 points and below.

The final categorisation of the female tea-pluckers is shown in Table 3.

Group 'A' tallies with the existing 'fast' category, and may be described as such. Groups 'C' and 'D' may be termed 'average' and 'slow' categories respectively, and are, in fact, seen to contain a mixture of those originally called 'average' and 'slow' pluckers. Group 'B', however, is comprised of so-called 'slow' pluckers who had some characteristics that equalled or exceeded those of the 'fast' group. On enquiry, it was found that both were newly recruited workers and therefore had low rates of daily output (and were hence categorised by the authorities as 'slow' pluckers). Group 'B' may therefore be said to describe a 'trainee' category; that is, one that would benefit immensely from training.

Conclusions

The utility of the new system of categorisation is to be found in the selection of workers. The parameters described above could help tea-garden authorities to decide which 'temporary' workers could be given 'permanent' status (ie – be confirmed in the jobs, with eligibility to allowances and other benefits). Secondly, this categorisation would help to select workers for training. The 'B' group identified above would be the ones on which to invest training profitably and who would show maximal improvements thereafter. Finally, to follow this categorisation would be a valid method for the formation of groups (eg, 'fast', 'average', 'slow') during future studies. If the groups themselves are incorrectly formed, it becomes extremely difficult, if not impossible, to identify the characteristic features of different types of pluckers.

Acknowledgement

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SEN R.N., MAJUMDAR D. (1.982)

Ergonomics in relation to occupational safety and health in jute industries in Eastern India

in PROCEEDINGS OF THE 10th ASIAN CONFERENCE ON OCCUPATIONAL HEALTH - SINGAPORE

Vol I p 289 - 298

One of the best and most alive report I have read about accidents in an industrially developing countries. The facts are terrible. Jute industry contributed in 1.979 about ~~54,3%~~ 55% of the total industry accident!

Average accident frequency rate per million man hours worked

1971-1977 X 219 % in jute industry

" X 46% all industries.

~~For~~ 17 causes
9 recommendations) very useful

EXCELLENT PAPER

SEN is more clinician than a physiologist

Ergonomics In Relation To Occupational Safety And Health In Jute Industries In Eastern India.

Sen R.N.*
and Majumdar D*

SUMMARY

One thousand accident reports of three jute mills of West Bengal were analysed to find out the distribution of accidents in the different sections of jute mills. The distribution of accidents by source types in each of the weaving, spinning and winding sections, the break up distribution of injuries according to the different body parts involved in the weaving, spinning, and winding sections and the hourly distribution of accidents in the above mentioned sections of three jute mills were done. It was found that one third (35.9%) and about one sixth (17.5%) of the total accidents occured in the weaving and spinning sections respectively. It was also clear that about one fifth (21.73%) of the injuries in the weaving section were caused by handknives which the weavers used for cutting the excess thread after knotting the broken weft/wrap threads but in the spinning section contact of hand of the spinners with the rotating flyer during piecing operation contributes about one third (36.57%) of the total injuries in the spinning section and about one fourth (25.25%) of the total injuries in the winding section, by striking against moving or fixed machine parts in the cop winding section. In the above three said sections, the miscellaneous accidents have been titled 'others' in the table, which also contributes a large figure. It is also revealed that the total finger/hand/forearm injuries (62.67%) in the weaving/spinning/winding sections were more pronounced, contributing three fifths of the total injuries. The weaving section with its high accident rate (35.9%) contributes to more than half (56.37%) of the total bodily injuries occurring in the three sections mentioned. It is concluded that effective safety measures should be taken to improve the working methods, safe design of tools, job training of workers, safety knowledge of workers, and to make the workers more aware of the most hazardous portion of the work, and increase job supervision.

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INTRODUCTION

Jute, as a crop of major economic importance in the world, is unique in many ways. The jute industry is the oldest and probably the very first of the organised industries in India that was set up during the last quarter of the 19th century. As a major foreign exchange earner it occupies an important and distinct place in the country's economy. There are sixty nine jute mills in the country of which sixty two are located in West Bengal. A large number of labourers are engaged in jute industries.

Most of the jute industries in India are at present being run in a very precarious and hazardous condition. The accident rate in this industry is the highest in the country involving huge loss of man-days, practically paralysing this industry and thereby affecting the country's economy to a great extent.

In a preliminary study it was found that the average accident frequency rate per million man-hours worked in the jute industry rose up to about 219% over a period of six years (1966-1977), whereas the rise in the average accident frequency rate of all other industries was by about 46% only (Banerjee & Chhabra, 1976). In the year 1979, the jute industry contributed about 54.54% of the total industrial accidents. But till now practically no work has been done regarding the different human factor problems, reduction of accidents, enhancing safety and improving occupational health and welfare of the workers in the jute industries.

It is most suprising that in all the sixty nine jute mills there are no separate accident prevention or safety units in the factories or even any qualified safety officer. There are no training programmes for the workers, supervisors or management staff in the factories, except the use of a few old safety posters and slogans on the walls of the factory sheds. Almost all the injuries are treated by the general E.S.I. (Employees State Insurance) Doctors outside the factory area or by the Doctor of the Health Service Unit employed by the factory itself, though such factories are very few in number (a few Govt. undertakings).

This paper presents a preliminary approach to find out the causes and distribution of different types of accidents in the different sections of jute mills. In addition, the different body parts involved in injuries and the hourly distribution of accidents in the weaving, spinning and winding sections of three jute mills in West Bengal are analysed and some recommendations, based on ergonomics principles are made.

Three sections are the sites of maximum occurances of accidents in jute mills, and the knife of the weavers and rotating flyer of the spining machines are the main agents of most of the 'cut and laceration' type of injuries.

METHODS AND MATERIALS

One thousand accident reports submitted by the three jute mills (total employment strength of 12,000) to the Factory Inspectorate, government of West Bengal in the year 1980-81 were analysed.

The accident data were analysed according to:—

1. the different sections.
2. the time of day
3. the incidents of accidents regarding types/sources
4. the different body parts involved.

SHIFTS

The arrangement of shifts in the jute industry is very peculiar. The morning shift or 'A' shift starts at 0600 hrs and ends at 1100 hrs for the first phase with a short break of 10-15 minutes for tea and snacks at 0700 hrs; the second phase of the shift starts at 1400 hrs and continues until 1700 hrs There is another break of 30 mins in this phase from 1500 hrs to 1530 hrs.

The 'back' or 'day' shift starts at 1100 hrs and continues up to 1400 hrs. This shift again starts after a break of three hours at 1700 hrs and continues until 2200 hrs, with a break for 15 mins at 1830 hrs.

The night or 'C' shift starts at 2200 hrs and continues up to 0600 hrs of the next day. There is 15 minutes tea break at 0300 hrs. The shifts are of a fortnight duration and rotate clockwise from A to B, B to C and C to A.

This type of staggering arrangement in the morning and day shifts are devised possibly to reduce the thermal load on the workers in the later morning and early afternoon hours. Moreover the residences of the workers are very near to the factory premises, so one can go home and rest, during the 3 hr. break between his shift. But with the increase in labour strength, the companies cannot provide residential facilities for all and the workers have to wait within the factory premises or outside because there are no separate rest rooms for them.

This arrangement of shifts may be one of the causes of the high rate of accidents in this industry, which has to be evaluated in order to show the impact of shift arrangements on accident rates.

ACCIDENT REPORT FORMS

The accident report forms, as used by all the jute mills of West Bengal for reporting accidents to the factory Inspectorate are not designed to elicit critical information of ergonomic significance. The report includes such general facts as the name of the worker, age, place of accident, body parts involved, type of injury, time of the shift, etc. In some cases the reports are incomplete. It seems that the accident report describes more about the effects rather than the causes of an accident. Moreover the maintenance of the accident report register is not good in most of the jute mills so far studied, and some of the jute mills are reluctant to give the accident report forms of analysis.

MANUFACTURING PROCESS

The jute manufacturing process in short, involves a series of sequential operations, namely, batching, carding, drawing, spinning, winding, beaming, weaving, cropping, calendering, lapping and sewing.

The hazardous and accident prone situations in these operations are the following:—

Batching section

a) The big root cutting knife without any safety guard.
b) Getting trapped in between flutted roller and cloth roller of the softening machine.

Preparing section

a) The cleaning of the jam of the small but pointed and sharp moving knife and the moving iron combs of the carding machine.
b) The packing weight hammer of the drawing machines.

Spinning section

a) Contact with the adjacent moving flyer & bobbins.

Winding section

a) Contact in between traverse rod and spindles during doffing in the cop winding machine.

b) Getting trapped in between spool and scroll.

Beaming section

a) Loading/unloading of beams.

b) Hands caught in the in-running nip of the rollers in the beaming machines.

Weaving section

a) Hand knife during cutting loose warp/weft ends.

b) Flying shuttle, sley, front rail, picking arm, etc.

c) Loading/unloading beam/cloth roll.

Finishing section

a) The piercing of fingers by rotating needle between pressure plate and chain of the over head sewing machines.

RESULTS AND DISCUSSIONS

Accidents in the different sections of the jute mills.

Table I shows the percentage of accidents (n = 1000) in the different sections of the three jute mills, in West Bengal. It has been observed that the maximum number of accidents, about one third of the total, (35.9%) occured in the weaving section, following by spinning, miscellaneous, finishing and winding sections. This unusually high rate of accidents in the weaving and spinning sections are thought to be due to:

1. The increased thermal and work loads.
2. The lack of training of the workers.
3. The use of unergonomically designed knife by weavers.
4. The insufficient space in between rotating flyers of the spinning machine.
5. Bad working methods.
6. Lack of maintenance of the weaving and spinning machines and machine parts (the machines are about seventy five to a hundred years old).
7. Insufficient working space.
8. Lack of sufficient supervision.
9. The man-machine incompatability (All the weaving and spinning machines were designed in European countries).
10. The increased number of untrained, unskilled casual workers.
11. The preponderence of hazardous portions in the work.
12. The workers intentionally getting minor injuries in order to avail themselves of the E.S.I. facilities, one or two days before the termination of their temporary job, especially in the case of casual workers.
13. Fatigue of workers, either physical or psychological in nature.
14. Unhealthy working environment.
15. The typical arrangement of shifts.
16. The intra-union rivalry (there are about seven to eight different unions in each jute mill).
17. Bad management-labour relations.

Hourly distribution of Accidents

Figure 1 gives the number of accidents occurring in each hour time slot of the day, over two years. It has also been found that the daily pattern is very consistent from year to year.

It is clear from the figure that in the weaving section most accidents occur in between 1100 hrs

Table I

Percentage of Accidents (N = 1000) in the different sections of three Jute Mills in West Bengal, India.

Sections							
Batching	Preparing	Spinning	Winding	Beaming	Weaving	Finishing	Miscellaneous
4.5	7.3	17.5	9.9	2.2	35.9	10.5	12.2

Batching = Root cutting, selection and softening and spreading by machine.
Preparing = Breaker and finisher carding and drawing.
Spinning = Spinning of the yarn.
Winding = Spool winding and cop winding by machine.
Beaming = Prebeaming and beaming.
Weaving = Hessian & sack weaving, narrow and broad loom.
Finishing = Cloth mending, inspection, calendering, lapping, sewing, etc.
Miscellaneous = Workshop, godown, canteen, etc.

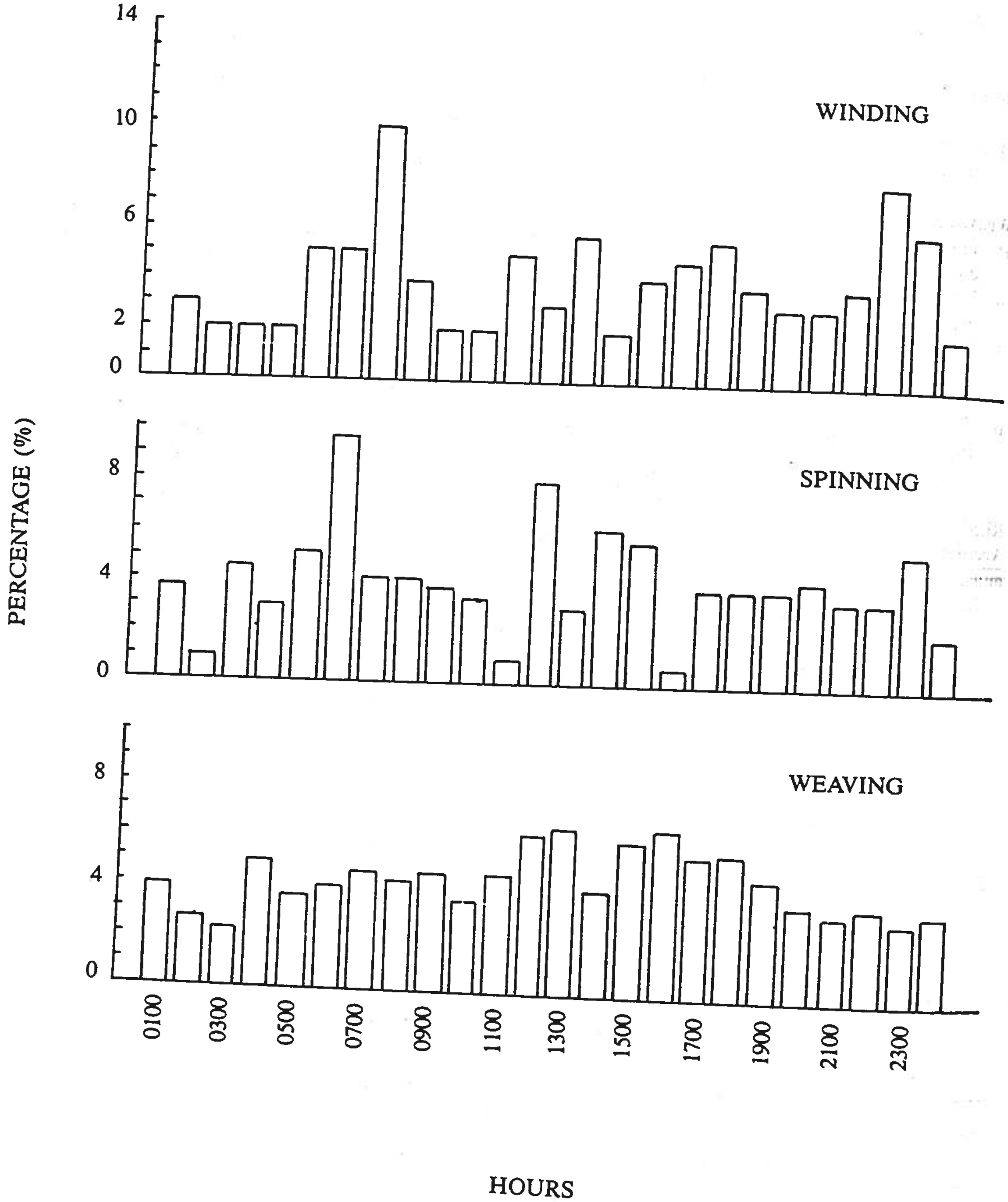

Figure 1. Hourly distribution of percentage of accidents in the weaving, spinning and winding sections of three jute factories in West Bengal, India. (n = 1000)

to 1300 hrs and between 1400 to 1600 hrs. This correlates well with observations in other industries that most accidents occur after mid morning (Powell et. al, 1971).

It may also be that the first peak of accidents in the weaving section and the second peak of accidents in the spinning section in between 1100 hrs to 1200 hrs are due to increased thermal stress during the mid-day. The maximum Corrected Effective Temperature value as obtained throughout the day is about 31.4°C at 1200 hrs.

The number of accidents appear to be directly related to the amount of work people do, (Powell et. al, 1971), and it is the general idea in our country that labourers of jute industries work under heavy physical work load. But it has been observed that the work load in weaving and spinning are moderate but never heavy (Sen et. al, 1969). The maximum pulse rates as observed for the weavers is 107 at 2200 hrs and 108 for the spinners at 1700 hrs.

The fewer localized peaks of accidents in the weaving, spinning and winding sections within one hour of the start of pre-or post-meal halves of the 'A' or 'B' shifts are thought to be due to the lack of awareness of the workers to the demands of the tasks, as it is suggested by others that the risk of injury increases as an employee settles into a job and his own pace picks up speed, the work pressure of the group intensifies (Adams et. at, 1981). We thought that the sharp peak of accidents in the spinning section which occurs at the end of night shift in between 0500 to 0600 hrs and the second peak of accidents in the winding section in between 2100 to 2200 hrs i.e. at the end of 'B' shift, appear to be mainly the effect of target setting by the operator as proposed by Powell et al (1971).

It has also been found that the weaving and winding sections produce fewer accidents in the night shift than in the morning and day shifts, similar to the observation in other industries by Adams, et al (1981) and Powell, et al (1971), but contrary to the idea of Froberg (1974) that the night shift produces relatively more injuries. But it has been found in a field study by the authors, that a major portion of the workers in the winding sections go to sleep frequently but for short periods during the night shift, due to the inadequate supply of bobbins from the spinning section. This is due to lack of supervision because there are no management staff present in the factor floor at that time.

Distribution of accidents by Type/Source in the weaving spinning and winding sections.

The "source or type of injury" indicates those element of man-machine or man-environment

Table II

Distribution of Accidents in the Weaving Department by Types/Source in three Jute Industries in West Bengal

Types/Source of Accidents	% of Accidents
1. Cutting loose warp/weft end by hand knife	21.73%
2. Struck by Picker, Pickingarm, picking strap	13.09%
3. Struck against moving or fixed machine parts	8.91%
4. Flying shuttle	7.8%
5. Handing with Beam/cloth roll, cloth centre	5.57%
6. Loading/Unloading beam/cloth roll/pinions	5.01%
7. Caught in between sley and front rail	4.74%
8. Fall of shuttle from shuttle rest on the loom	4.18%
9. Defective Floor (Slippery, Broken, Uneven)	3.9%
10. Shuttle - Cop fitting, Setting on looms, Shuttle box rail	3.34%
11. Caught in between pinions	3.06%
12. Loose/Sharp objects on floor or on the working platform	1.95%
13. Beam dragging trolley	1.67%
14. Broken loom spindle	1.67%
15. Caught in between V-belts & Pulley	1.39%
16. Caught in between pin roller/cloth roller	0.84%
17. Others	11.14%

system which directly cause the accident or precipitate the injurious movement (e.g. defective floor). In the weaving seventeen, in the spinning, ten and in the winding, eighteen, such sources or types of accidents are listed. Table II, III & IV list these sources in their order of frequency of occurence.

Most interesting among the data in the tables are the following:—

Table II

The hand knife of the weaver is a potent source of accidents and causes 21.73% of the injuries in the weaving section. It has been found that there are no specially designed knife for them to use and the knife is not even supplied by the factory. They purchase it from the open market. So the knives vary in shape and size from person to person. The sharp edge of the knife remains free to cut the yarn and during this operation they cut their fingers accidentally or purposely, (Adams et al, 1981).

The second and third items in Table II i.e. striking against picker, picking arm, picking strap and moving or fixed machine parts, contribute 22% of the total injuries in the weaving section. The result indicates either the use of wrong working methods and lack of safety measures on part of the worker or unsafe conditions.

The fifth and sixth items in Table II also indicates the use of unergonomic ways of loading/unloading leading to severe low back pain of the employees.

All the above results and observations suggest that the employees' work methods should be improved by training as proposed by Adam, et al, (1981). Moreover the factory should provide ergonomically designed safe hand knives to the weavers in order to reduce the hand knife injury.

The flying shuttle contributes 7.8% of the total accidents in the weaving section, and is due to the lack of maintenance of the loom and shuttles.

Other accidents like item No. 7 occur because of the unsafe act of the weavers though there is a two-inch gap in between sley and front rail in accordance with factory rules.

The accidental fall of the shuttle from the shuttle rest on the loom is due either to the improper fitting of the shuttle to the shuttle rest so that it falls down due to the vibration of the loom while moving.

The factory floor is most unclean, and 1.95% of the total injuries in the weaving section are due to loose or sharp objects lying on the floor. Regular cleaning of the floor is advised. Simultaneously the workers should be advised not to work bare footed.

Some other minor accidents contribute to 11.14% of the accidents, the third highest item in the weaving section. The causes behind some

Table III

Distribution of Accidents in the Spinning Department by Types/Source in three Jute Industries in West Bengal

Types/Source of Accidents	% of Accidents
1. Contact with rotating flyer during piecing	36.57%
2. Contact with rotating flyer during doffing/placing bobbins	15.43%
3. Bobbin fly	10.28%
4. Defective floor (Slippery, Broken, Uneven)	5.14%
5. Finger entangled with spinning hooks during piecing	4.57%
6. Trolley	4.57%
7. Fall of silver can and silver can sharp edge	3.43%
8. Cleaning operation:	
a) Fall of pressing roller	3.43%
b) Fall of carriage	0.57%
c) Fall from rail during cleaning pneumaphil	1.14%
d) Use of knife	1.71%
e) Contact with rotating flyer during cleaning jam in the flyer	1.71%
9. Loose/Sharp objects on the floor	2.86%
10. Others	8.57%

of the injuries are not known. Most of them occur through unsafe acts of the workers though unsafe conditions also contribute to a major portion of this type of accident.

Table III

Most interesting among the data in the spinning section are items 1 and 2, where the rotating flyer contributes to more than 50% of all the accidents in the spinning section. The victims in item 2 (15.43%) are the shifter boys who either remove full bobbins or place empty bobbins in the bobbin rail. In item 1, the spinners actually get in contact with the neighbouring rotating flyer during 'piecing' operation. These types of accidents are thought to be due to the,

a) insufficient space in between flyers from the ergonomic point of view and,
(b) inadequate distance from bobbin top in the rail to the rotating flyer.

The next highest source of accidents, the bobbin fly, is thought to be due to lack of maintenance of the spinning machine. Regular checking of the machine will reduce this type of accident.

It is also recommended that spinning hooks should be ergonomically designed to ensure safety and reduce the total spinning injuries.

The cleaning operation contributes 8.56% of the total accidents in the spinning section. Whether this is due to unsafe act, or unsafe condition, or lack of maintenance of the machine remains unclear.

Other minor accidents contribute a large proportion (8.57%) of the accidents in the spinning section. These accidents occur due to varying reasons, some of which are unexplainable, like sudden unconsciousness of a worker without any known neural or psychic disorder.

Table IV

Distribution of Accidents in the Winding Department by Types/Source in three Jute Factories in West Bengal

Types/Source of Accidents	% of Accidents
Cop. Winding Section:	
1. Struck against moving or fixed machine parts (bobbin top, front cover, bobbin thread, guide, moving sprindle, traverse rod, clutch)	25.25%
2. Fall of bobbin from reel	6.06%
3. Caught in between spindle and wheel during cleaning, jam in the spindle or yarn entangled in the finger	5.05%
4. Trolley	5.05%
5. Use of knife for cleaning or knot cutting	4.04%
6. Fall of spindle, Cop	3.03%
7. Flying Top nut of spindle	2.02%
8. Others	7.07%
Spool Winding Section:	
1. Use of knife, knot cutter and scissors	7.07%
2. Caught in between spool and scroll	6.06%
3. Struck against moving of fixed machine parts (spindle, spool lever, scroll, thread guide, spool)	5.05%
4. Trolley	4.04%
5. Fall of spool	3.03%
6. Fall of bobbin	2.02%
7. Caught in between spool and spindle	2.02%
8. Others	4.04%
Common accidents	
1. Loose/sharp objects on floor	**5.05%**
2. Defective floor (Slippery, Broken, Uneven)	**4.04%**

Table IV

The characteristic item in the winding section, is 'striking against moving or fixed machine parts'. The cop winding section alone contributes 25.25% of these accidents. In the spool winding section it shows a figure of 5.05%. The results suggest the need for safe work procedures and the removal of unsafe working sconditions. The workers lack knowledge of safety which should be remedied by periodic short term shop floor training.

Fall of bobbin or of spool, spindle and cop also produces a large proportion (14.11%) of the total accidents in the winding section. These accidents are due to improper machine design.

Like the weaving section the spool winders also get themselves injured by the same poorly designed hand knife. It is suggested that proper care should be taken by the factory owners about the hand knife used by the workers in the jute factories.

The accidents grouped as 'others' contributing 11.11% of all accidents are of diverse nature and involve unexplained causes, like vaso-vagal attacks, sudden unconsciousness etc.

Accidents due to loose/sharp objects on the floor (5.05%) reflect untidiness of the floor. Hourly cleaning of the floor surface would imporve the general quality of house-keeping.

Tables II, III & IV reveal that defective, slippery, uneven and broken floor sufaces have produced, 3.9%, 5.14% and 4.04% of the accidents in the weaving, spinning and winding sections respectively. Clearly, the improvement of floor surfaces where practicable should minimise this significant contribution to accidents.

Another interesting item in Table II, III & IV is the accident from 'trolley', which is contributing 1.67% in the weaving department, 4.57% in the spinning section and 9.09% in the winding section. The pusher of the trolley actually gets the injury from the trolley either on the foot or leg due to the uneven or broken surface of the shop floor or strike against some obstacles. Good house keeping and floor maintenance will reduce this kind of accident.

Different body parts involved

Table V describes the percentage distribution of injuries according to the different body parts involved in the weaving, spinning and winding sections.

Though the total number of accidents in the weaving and spinning sections are 357 and 175, the total number of injuries are 367 and 185 respectively, because some of the injuries are of multiple nature involving more than one body part.

The table shows that weaving department alone has contributed more than 50% of the total bodily injuries, followed by spinning and winding sections contributing 28.42% and

Table V

Break up of percentage Distribution of Injuries According to the Different Body parts Involved in the Weaving, Spining and Winding sections of three Jute Industries in West Bengal

Department	Different Body Part Involved (% distribution)						Percentage of All Injuries*
	Finger/ Hand/ Forearm	Foot/ leg	Trunk	Head/ Neck	Testis/ inguinal region		
Weaving (n = 367)	62.12	18.53	10.08	7.91	1.36	100.00	56.37
Spinning (n = 185)	68.11	15.67	5.95	9.19	1.08	100.00	28.42
Winding (n = 99)	54.55	33.33	2.02	7.07	3.03	100.00	15.21
% of all Insuries**	62.67	19.97	7.68	8.14	1.54	100.00	—

**: The percentage contribution of each department.*

***: The percentage contribution of individual injury sites (three departments inclusive)*

15.21% respectively.

It is also seen that finger/hand/forearm injury has contributed 62.67% i.e. three-fifth of all the injuries.

Though the weaving section contributes more than half of the total injuries, it produces the most injuries in the trunk (10.08%) while the spinning section has two main types of injuries, one in finger/hand/forearm (68.11%) and other in hand/neck (9.19%). The winding section contributes most injuries in foot/leg (33.33%) and testis and inguinal region (3.03%)

The finger/hand/forearm injuries originate mainly from the weaver's hand knife, and rotating flyer of the spinning machine. The contribution of sley and front rail, shuttle, shuttle box rail, picker, picking arm and picking strap, spinning hooks, spindle, spool and scroll of the winding machine are also noticeable.

The foot/leg injuries are due to the fall of bobbin, spindle, cop, spool, top nut of spindle and front cover of winding machine, the fall of shuttle from shuttle rest of loom, loose/sharp objects on floor, defective floor, trolley, beam, beam flange etc.

The trunk injuries occur during loading/unloading of beam/cloth roll/pinions, fall in the floor due to defective floor surface, flying shuttle and top nut of spindle, and strucking against moving or fixed machine parts.

The head/neck injuries involve sudden unconsciousness, vaso-vagal attacks, falls on the floor due to rough floor surface, and foreign particles in the eye.

The testis/inguinal region injuries come from the bobbin fly, shuttle fly, top nut fly and by striking against moving or fixed machine parts.

These results indicate that all the injuries are due to either the use of bad working methods, unsafe acts by the workers, or the lack of maintenance of machines, unergonomic design of hand tools and machinery, unsafe conditions and unhealthy working environment in the shop floor. Further research on this matter will definitely elucidate the contribution of different accidents in individual injury, basic causes behind the individual injury and necessary remedial measures to be taken to improve the occupational health and safety of the workers.

CONCLUSION

The following suggestion based on the information presented in this paper are put forward for consideration:—

1. The injury reporting system should be improved by employing ergonomically designed accident report forms to give more details and causative information about accidents.
2. Each and every jute mill should have a separate health and safety unit guided by a qualified safety officer.
3. The management in every factory should initiate short training programmes on safety and occupational health.
4. The general pattern of supervision of different shifts should be improved. The ratio of supervisors to workers should be increased.
5. The ventilation arrangements in the working area should be improved to reduce the thermal load and fatiguability and to improve the physical performance of the labourers. This can easily be done by opening windows and having saw tooth roofs in the facory shed.
6. The maintenance of the different machines should be improved.
7. The hand knife of the weaver and the spinning hook should be more ergonomically designed.
8. The management should take proper care in 'piecing' operation in the spinning department, as well as in the 'doffing' and 'placing' of bobbins in the bobbin rail of spinning machines.
9. The authors also support the recommendations of Adams et al (1981) that there should be instituted, in at least some work places, with high injury rates, a system to record near-miss situtations in which an unsafe behaviour or circumstance has been evident. This kind of research would need the cooperation of employers, employees and unions. Such cooperation is well worth seeking, because it is only through this sort of study that really valid inferences can be drawn about the hazard potential and/or injury potential of a particular behaviour or situation.

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SEN R.N, GANGULI A.K. (1982) (1)

Preliminary investigations into the loco-man factor in the Indian railways

APPLIED ERGONOMICS 13 2 107.117

1.520.000 ~~million~~ men employed.

Information gathered in 3 ways:

1) interview with drivers and traction staff
2) administration of a questionnaire
3) observation during run

Bias A strong impression was formed that the drivers were biased in the following main ways:

1) to give an exaggerated impression of their skills and abilities
2) to exaggerate the bad points of the work conditions
3) to make the job seem more difficult than it might be

[This is a typical remark of a psychologist who works inside ~~with~~ psychosociology and sociology with no theoretical background. This research is doubtful]

According to the train timings, drivers get up to 24h rest in between runs (minimum 8h) // typical

VERY GOOD FIGURE p 110 on variable visibility of signals with weather

Good remarks on lighting, rear view mirrors, Seats very good results p 111

Thermal environment very good results p 112

you can feel very cold in winter nights in INDIA

Ladder much too high steps

Excellent results on anthropometry, physiology, vision, etc

But nothing serious about cognitive load : even ill appreciation of it. Conclusion is typical of an excellent old fashion ergonomic work analysis:

" In a situation where 3 out of every 5 accidents [everybody knows how wrong is this classification] are thought to be due to human error, the deficiencies in the working condition and environment outlined above assumed greater significance. The lack of biomechanical and anthropometric considerations in the design of the work station, the irregularities of the "link" system, improper cabin/instrument illumination, and the poor seats are particularly disturbing in this report. The results indicate that the next part of the investigation should be devoted to the collection of anthropometric and psychophysiological data [and not analyses!] on the drivers to be followed by the formulation of different design alternatives. The alternatives would be the basis of 1/1 mock ups which would be evaluated using driver opinions. The "link"

as it is not directly relevant to the primary objective (3)
of the present study : the design of driver's cabin

—

SEN R.N, GANGULI A.K. (1.982)

An ergonomic analysis of railway locomotive driver functions in INDIA

JOURNAL OF HUMAN ERGOLOGY 11 187.202

"Driving a railway locomotive in India is a highly demanding and complicated job in which each of the components of a man-machine environment system is involved in the driver's task. The driver has to receive a large volume of information output such as signals, displays, conversation with the assistant driver, sensory cues etc ......"

[All this is very true but why does SEN says the contrary the same year in APPLIED ERGONOMICS ??]

[He uses the very classical time and motion study division

requirements

↓

Tasks

↓

Operation

where no place is left for memory, adjustments, ~~[illegible]~~ control, functional representation, adaptative behaviour to driving circumstances, prevention of incidents and accidents. Driving a train ~~is~~ is a process-control activity]

Very interesting description [no relation with the formal enquiry] about : work aspects of job

- training
- assistant presence

Interesting remarks

50% of the first level function cannot be done or well done in relation with the cabin characteristics ; especially there is no communication with the external world except for band and light signals [see recent accidents in french railways]

Den is very clever , he has seen many things but his method is a bad MTM method and his approach to changes is old fashion , seats and dials " ergonomics that is bad for this situation ". It doesn't mean that this ~~report~~ report is bad but very limited

J. Human Ergol., **11**: 187–202, 1982

AN ERGONOMIC ANALYSIS OF RAILWAY LOCOMOTIVE DRIVER FUNCTIONS IN INDIA

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A 3-tiered analysis of electric locomotive driver functions in India and a task-operation-subsystem analysis based on a Function-Subsystem Matrix are presented using data derived from interviews with railway drivers and supervisory personnel, drivers' responses to a questionnaire, and observations during actual running of trains. The functional analyses break down the train driving job into requirements, tasks and operations, in increasing degrees of detail. From the matrix, a subsystem utilization analysis, an operations frequency analysis, and a task complexity analysis have been performed. The findings showed a high degree of correlation with similar published analyses in American railways. Recommendations have been made regarding the position of controls (brake, horn), and displays (speedometer, traction motor current, and voltage meters). Use of auditory channels for warning indications, and installation of in-cabin signalling devices have been advocated so as to decrease perceptual loads and improve safety. It is suggested that operational safety and efficiency cannot be obtained without proper design of the controls, displays, work-space, and work-environment of the railway driver's cabin.

Driving a railway locomotive in India is a highly demanding and complicated job, in which each of the components of a man-machine-environment system is involved as the driver's task. The driver has to receive a large volume of information inputs, such as signals, displays, conversation with the assistant driver, sensory cues, *etc*. From these, he has to select the items which deserve processing, and search for additional information from short-term memory (position of the train, caution orders in force) or long term storage (mental pictures of the track section, known dynamic characteristics of the locomotive). In fact, the situation is not one where there is a dearth of information, but rather one reflecting improper presentation of information due to defects in the work organi-

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zation and the design of the work place. Bad weather, poor illumination, glare, thermal stress, noise, and vibration are among the numerous physical influences which affect both the reception and the processing of information. The resulting decisions give rise to effector actions of control which govern the behavior of the train. On these decisions of the driver depend numerous lives and property.

The Indian Railways are the biggest single industry in the country, from the point of view of both the capital invested and the labour employed. There are over 1.7 million workers. Unfortunately the Indian Railways has one of the highest accident rates in the world, though the incidence is considerably decreased when expressed in terms of million kilometers travelled or million passengers carried. In this context, it is interesting to note that as much as 60% of all railway accidents in the country have been ascribed to the human (loco-man) factor (South Eastern Railway Safety Organization, 1979).

Locomotives in use on the Indian Railways are either designed as well as manufactured in foreign countries (Japan, U. S. A., Federal Republic of Germany) or manufactured in India based on foreign designs. Yet no design allowances appear to have been made for the different population of men who operate them, and to our knowledge, no studies have been published on the ergonomic aspects of the skills of train driving under Indian conditions.

The objectives of the study are to perform an in-depth ergonomic analysis of the existing locomotive cabin environment, the design of the controls and displays in it, and the driver's job requirements; and thereafter to provide design recommendations on both a short and long term basis. In the present paper, we present 1) a 3-tiered functional (work-activity) analysis of driver functions in terms of requirements, tasks, and operations, and 2) a task-operation-subsystem analysis based on a function-subsystem matrix, especially with respect to the operational requirements of and stresses on the drivers, and to the desing of the controls and displays in the cabin.

MATERIALS AND METHODS

The information required for the analyses was gathered in three ways: (1) interviews with drivers, and traction staff, (2) drivers' responses to a questionnaire, and (3) observation of driver activities during actual running conditions. The questionnaire used was predominantly of the multiple choice type. The replies were collected from the drivers. The topics covered were: (1) the drivers' backgrounds, and general information (including training, welfare facilities, medical background, *etc.*); (2) duty hours, leave, *etc.*; (3) duties and procedures; (4) signals and indications to be monitored or exchanged; (5) visibility factors (glare, weather conditions, windshield, *etc.*); (6) the internal environment of the cabin (including heat, dust, noise, vibration, illumination, work-space, seating *etc.*); (7) special skills like monitoring of track, braking behavior, and so on; and (8) accidents and critical incidents.

The derived data were analyzed by means of a 3-tiered analysis of driver, functions and a matrix analysis method. The obtained results were then compared with those reported from the American railways.

The following is a glossary of terms used for the analysis.

Job: A regular, renumerative employment; a piece of work, or actual process of doing a piece of work.

Task: A specific or assigned piece or amount of work, often required or expected to be finished within a certain time.

Operation: Doing or performing a practical work or process, especially as a part of a series of actions.

Consist: The full assembly of a train, including locomotive(s), coaches and vans.

Shorts: Short assemblies of coaches which are attached or detached at intermediate points on a journey.

Points/Cross-overs: Places where tracks merge, bifurcate or cross-over.

Neutral Section: Section of track where there is no voltage or tension in the overhead wires.

Sonny: Name given to auditory warning of excess current in motors (present in a few locomotives only).

Functional analysis. The job of train driving was first broken down (by the first level analysis) into various "requirements." These requirements (level 1 functions) were again broken down by the second level analysis into "Tasks" (level 2 functions), which the third level analysis further broke into "Operations" (level 3 functions). Thus the functional analysis takes us from the general to the particular, and is therefore deductive and not inductive in nature.

The method used was a modification of the analysis by ROBINSON *et al.* (1976), in their study on locomotive cabin design development which was sponsored by the U. S. Department of Transportation, Federal Railroad Administration, though they did not rank their functions or identify sequential/non-sequential portions in the level 2 analysis. This functional analysis method may be considered to be a method-study approach to the train driving job. It may be described as work activity analysis in the method-study terminology. The level 2 functions (Tasks) describe the work content, and are broken down by the level 3 analysis into macromotions (here described as Operations), which one could further subdivide into elements by a micromotion analysis.

While most of the design approaches are based on subjective applications of ergonomic principles, the efficacy of the three-tiered functional analysis lies in its objectivity, being based on the operations actually performed. The systematic listing ensures that no factor is under- or over-emphasized in a complex design environment. Moreover, the outputs from the matrix and subsystem analysis are quantitative in nature and may serve as inputs for linear programming and

Level-2 functions (tasks) / Subsystems and subsystem activities (operations)	Propulsion system	Insert/Remove levers	Set travel direction	Apply/Release tractive effort	Apply/Remove shunt fields	Read notch indicator	Train brake system	Apply/Release brake	Read brake pipe pressure	Read equaliser pressure	Hear pressure venting	Read/Compare speed	Estimate speed/Distance
Register with ATF													
Check loco		●							●	●			
Open loco to traffic													
Take loco to station/ Form train consist			●	●	●	●							
Check train consist								●	●	●	●		
Obtain proceed signal													
Start train			●	●	●	●		●	●	●		●	●
Move to main track				●	●	●							
Achieve speed				●	●	●		●	●	●	●	●	●
Detach/Attach shorts								●	●	●	●		
Respond to/Transmit signals				●	●	●		●	●	●	●	●	●
Monitor loco systems									●	●			
Manage auxiliary systems													
Negotiate cross overs				●	●	●		●	●	●	●		●
Negotiate neutral section				●	●			●	●	●			
Negotiate gradients				●	●	●		●	●	●	●	●	●
Negotiate curves				●				●	●	●	●	●	●
Pass trains & equipment													
Decelerate train				●	●	●		●	●	●	●	●	●
Leave main track				●	●	●							
Stop train				●				●	●	●	●	●	●
Take train to yard/ Detach loco			●	●	●	●		●	●	●	●	●	●
Take loco to shed			●	●	●	●							
Sign arrival log		●											
Column totals		2	4	14	12	11		12	14	14	10	8	9
System totals				43							75		

Fig. 1.

other mathematical models.

Matrix analysis. The matrix analysis method involved setting up of a matrix, as shown in Fig. 1. The matrix had the level 2 functions on one axis, and each of the locomotive subsystems (such as brake, propulsion, *etc.*) on the other. Con-

Operate isolater pedal	Loco brake system	Apply/Release brake	Read brake cylinder pressure	Hear pressure venting	Estimate speed/Distance	Pneumatic system	Read main reservoir pressure	Switch on/off compressor	Switch on/off exhauster	Drive system	Read speed	Monitor wheel slip	Check auto sanding	Apply manual sand	Electrical system	Insert/Remove switch lock	Raise/Lower pantograph	Check battery charging	Open/Reset circuit breaker
		●	●	●			●	●	●							●	●	●	●
		●	●	●	●							●							
							●												
		●	●	●	●						●	●	●	●					
		●	●	●	●						●	●							
●		●	●	●	●						●	●	●	●					
●		●	●	●	●						●								
			●				●				●	●	●						
●		●	●	●	●						●	●							
		●			●		●				●	●					●	●	●
●											●	●	●	●					
●		●	●	●	●						●	●	●	●					
●		●	●	●	●						●	●	●	●					
		●	●	●	●						●	●							
●		●	●	●	●						●	●	●	●					
●		●	●	●	●		●				●	●	●	●			●		●
		●	●	●	●		●				●	●					●	●	●
								●	●							●			
8		14	14	13	13		6	2	2		14	14	8	7		2	4	3	4
			54					10				43							20

Function-subsystem matrix

sidering each level 2 function in turn, an entry was made in the matrix corresponding to the sub-system activity (level 3 function) necessary to carry out that task. For example, to perform the level 2 function 'start train,' the driver would have to operate the propulsion system and the brake system, then he would have to

Level-2 functions (tasks)	Subsystem and subsystem activities (operations)	Check/Set switches	Read catenary/Motor voltage	Check lights/Bulb fuses	Engine system	Switch On/Off blower	Read traction motor current	Hear Sonny	Internal information	Read cabin signals	Read caution order	Confer with assistant driver	External environment	Read block signals	Read restrictive signals
Register with ATF															
Check loco		●	●	●		●				●	●	●			
Open loco to traffic															
Take loco to station/ Form train consist												●			
Check train consist															
Obtain proceed signal												●		●	
Start train			●				●			●	●	●		●	●
Move to main track											●	●		●	●
Achieve speed							●	●		●	●	●		●	●
Detach/Attach shorts											●	●			
Respond to/Transmit signals										●	●	●		●	●
Monitor loco systems			●				●	●		●		●			
Manage auxiliary systems												●			
Negotiate cross overs											●	●		●	●
Negotiate neutral section			●							●	●	●		●	●
Negotiate gradients							●	●		●	●	●		●	●
Negotiate curves										●	●	●		●	●
Pass trains 8 equipment															
Decelerate train										●	●	●		●	●
Leave main track											●	●		●	●
Stop train										●	●	●		●	●
Take train to yard/ Detach loco										●		●		●	
Take loco to shed												●			
Sign arrival log		●								●					
Column totals		2	4	1		2	4	3		12	13	19		13	11
System totals							9				44				

Fig. 1.

monitor the caution orders and deal with cabin instruments, signals, and so on. In each case, a dot is put at the appropriate spot on the matrix.

After all the level 2 functions were so analysed, the number of matrix entries for each 'Task,' 'Subsystem,' and 'Operation' (sub-system activity) were counted.

Read/Give hand signals	Hear/Sound horn	Monitor obstructions/Track condition	Monitor parallel track	Monitor overhead equipment	Perform roll-by inspection	Monitor own train	Lighting system	Manage cabin lamps	Manage engine compartment lamps	Manage instrument lamps	Manage marker lamps	Switch on/off headlight	Dim headlight	Miscellaneous	Manage look out glass	Operate wipers	Operate fan/Heaters	Paper work (external)	Row totals
																		●	1
								●	●	●	●	●			●	●	●		28
																		●	1
●	●	●																	13
																		●	6
●																			3
	●	●	●	●		●													29
●	●	●	●	●															18
	●	●	●	●															29
●																		●	8
●	●																		22
						●													13
								●	●	●	●	●			●	●	●		9
●	●	●	●	●															24
				●									●						21
		●	●	●															24
	●	●	●	●		●													26
●	●				●								●						4
		●	●	●															26
●	●	●	●	●															18
●		●	●									●							25
●	●	●	●	●							●	●						●	33
●	●	●	●	●								●							21
								●	●	●	●	●						●	13
11	11	12	11	11	1	3		3	3	3	4	6	2		2	2	2	6	
		84								21						12			415

Continued.

These counts form the basis of different rank orders.

Comparisons. The level 1 functional analysis, the level 2 functional analysis, and the subsystem utilization analysis were compared with those reported by Robinson *et al.* (1976). As we are unaware of similar analyses with respect to other foreign railways, the comparisons had to be restricted to the American railways.

RESULTS AND DISCUSSIONS

Questionnaire

The first two sections of the questionnaire covered working conditions. When asked to list the worst aspects of their job, drivers responded as follows: long/irregular duty hours, 15.6%; insufficient rest, 11.1%; low pay, particularly in relation to responsibility, 11.1%; insufficient housing facilities, 11.1%; high mental load, 8.9%; unpredictable or bad signalling system, 8.9%; bad behavior of superiors, 8.9%; and other factors 24.4%.

Only 25% of the drivers felt that the training which they received was "thorough." Forty percent felt that it was "just adequate," and 35% considered it to be "insufficient." They pointed out that they received very little practical training and that they found that actual conditions were quite different from the theoretical ones.

All drivers considered the assistant driver's presence to be necessary, though 5% thought that the assistant driver (fireman) was "important" and the rest 95% thought that he was "essential."

Eighty percent of the drivers admitted that monotony or drowsiness effects occurred. About the time of onset of monotony or drowsiness, 3.3% mentioned 2200–2300 hr, 3.3% 2300–2400, 6.7% 2400–0100, 6.7% 0100–0200, 26.7% 0200–0300, 20.0% 0300–0400, 23.3% 0400–0500, 6.7% 0500–0600, and 3.3% 0600–0700.

Of the drivers, 35.5% said they often splashed water on their eyes and face to keep themselves alert, 25.8% drank tea, and 16.1% adopted a standing posture. Other miscellaneous measures such as smoking, conversation with the assistant driver, were reported by the other 22.6%.

The third section of the questionnaire dealt with the duties and procedures, and these responses have been presented in Figs. 2 and 3.

Results from the sections four, five and six of the questionnaire dealt with the internal and external working environment, and are found elsewhere (SEN and GANGULI, 1982). Responses to sections seven and eight were subjective/descriptive in nature, and have been discussed in the relevant areas below. SEN and GANGULI (1982) made an approach towards driver cabin design from the work environment point of view such as control-display analysis, *etc.* The present paper describes the work content and conditions approach to the same design problem. It is by integration of the results obtained from these two approaches that the final design may be arrived at.

First level functions

The first level (level 1) functions in Table 1 give the summary of the operational

Table 1. First-Level functions.

Importance	Functional Principles	Suitability of the present design with respect to the function
1.	Operational Safety and Reliability	?
2.	Exchange of Signals between Man-Machine and Man-Environment	??
3.	Range of Speeds	
4.	Rapid deceleration	?
5.	Range of loads to be carried	
6.	Mix of types of cars forming the consist	?
7.	Negotiation of Gradients and Curves	
8.	Variety of Track Conditions	?
9.	Variety of Environments	??
10.	Day/Night operation	?
11.	Bi-Directional Movement	
12.	Fault Indication and Isolation	
13.	Operation in Multiple (Helper) units.	

requirements, representing the most complex functional needs of the driver and his cabin. They are determined from the opinions expressed by the drivers. The number of query marks (?) alongside the entries indicate that the present cabin is unsuitable for the functions required of it in more than 50% of the cases. For example, there are absolutely no means by which the driver of such a running locomotive can communicate with the external world (including the guard), except by hand or light signals, though this is an important primary requirement. In fact, communicating with the external environment is the most important requirement, as shown by the systems analysis presented later.

Reference to the analysis by Robinson, *et al.* (1976) makes it possible for us to compare the requirements listed above with those of the American railways. On comparison, it may be seen that most of the items listed are similar in both cases, though "rapid deceleration" and "fault indication and isolation" were not considered to be level 1 functions by those authors. On the other hand, they have placed added emphasis on "multiple unit operation" defining the multiple unit as more than one locomotive in a train assembly. This is presumably because the terrain in the United States requires that this be a frequent mode of operation. Since they did not rank their functions, priority comparisons with their data were not possible.

Second level functions

The next level of systems analysis leads to the definition of second level (level 2) functions (Fig. 2). These are the actions required of the driving crew to fulfil the requirements set out in the level 1 analysis. Alternatively, they may be looked upon as a task-by-task breakdown of train driving.

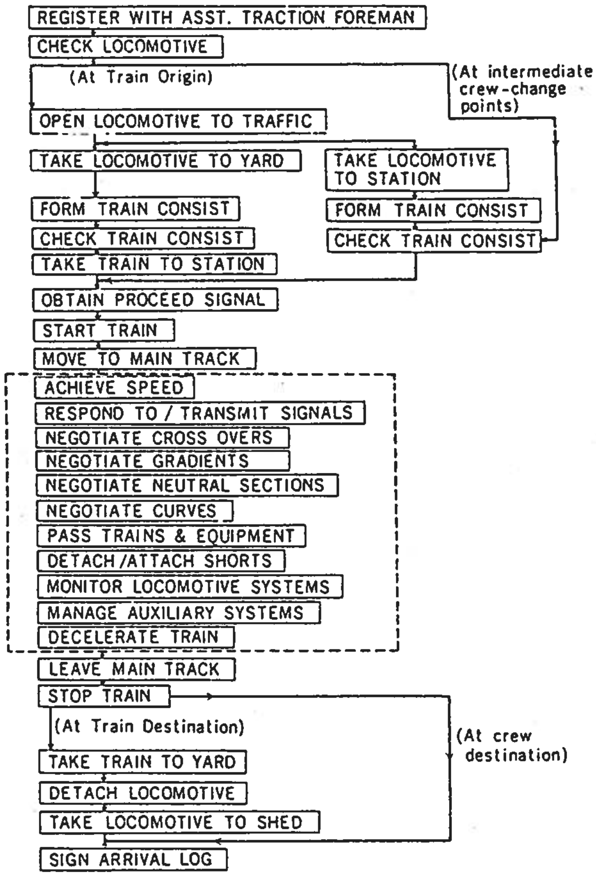

Fig. 2. Second level functional analysis (passenger traffic: mail/express).

Three distinct sections can be seen in Fig. 3. The first section consists of sequential operations, and extends from the "register with assistant traction foreman" entry to the "achieve speed" entry. There are three possible alternative directions of flow within this section. The first two relate to 'Tasks' that have to be performed at the train origin, where the driver has to form the consist (which is composed of locomotive (s), coaches, luggage van(s), and so on). In one case the driver has to form the consist at the yard, and take it to the station. In the second case, the driver takes the locomotive to the station directly, and forms the consist there. The third possible route relates to intermediate crew-change points, where the driver takes charge of the consist from another driver (who has brought the consist to the intermediate point).

The second section ("achieve speed" to "decelerate train") is comprised of "Tasks" which are non-sequential in nature. These may be performed in any order and any number of times during a run, according to operational requirements.

The third section begins from the "decelerate train" entry, and ends at the "sign arrival log" entry. The tasks in this section are also performed sequentially. There are two possible routes, one relating to the train destination, and the other to the intermediate crew-change points. Thus, the whole activity consists of one large cycle, within which there may be several predictable and unpredictable

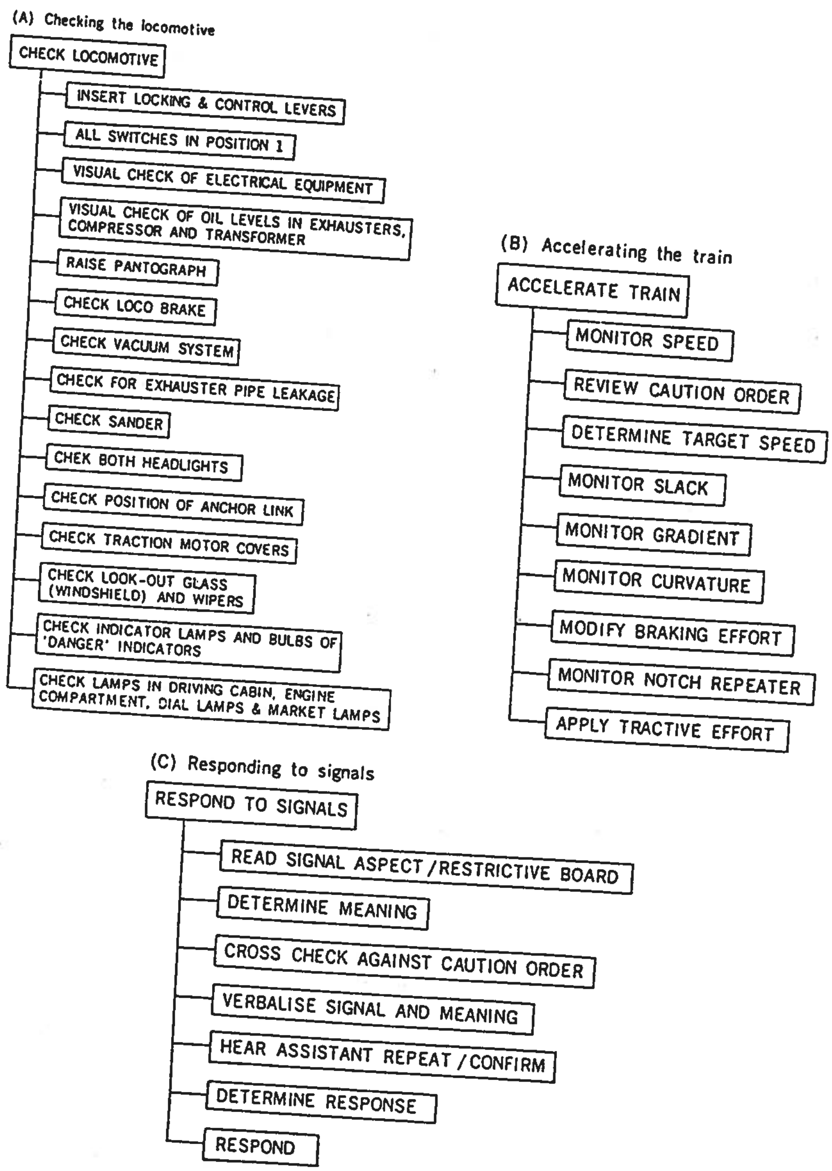

Fig. 3. Typical third level functions of a locomotive driver.

Table 2. Rank order of locomotive sub-systems (Sen and Ganguli, 1982).

Rank		Sub-system	Matrix entries
1.		Monitoring/Communicating with External Environment	84
2.		Train (Vacuum) Brake System	75
3.		Locomotive (Air) Brake System	54
4.		Internal Signals/Communications/Information	44
5.	(5.5)	Propulsion System	43
5.	(5.5)	Driving System	43
7.		Lighting System	21
8.		Electrical System	20
9.		Miscellaneous/Auxiliary Systems	12
10.		Pneumatic System	10
11.		Engine (Traction Motor) System	9

Figures in the parentheses represent alternative ranking.

subcycles. Comparison with the analysis by Robinson *et al.*, (1976) shows that there are three main differences. Two items in the above list are missing in theirs. The first relates to the shunting activities the locomotive drivers have to perform in India, but which are carried out strictly by specialized locomotives in the United States. The second is a functional component relating to on-run tasks, "negotiate neutral section"; presumably it is missing in their analysis because it relates to only electric locomotives, while the Robinson analysis was done with respect to diesel/diesel-electric locomotives. The third difference is an item present in their list, but missing in the present one. This relates to Multiple-Unit operation, and its relative importance in the two countries has been discussed earlier (level 1 functions).

Third level functions

In a similar way, each of the level 2 functions were broken down into third level (level 3) functions. Thus, the level 3 functions represent the operation-by-operation breakdown of the jobs described in the level 2 analysis. The primary aim is to provide the baseline for a systematic listing of the control display requirements and the activities to which they are associated. Figure 3(A) shows a typical level 3 function. The "check locomotive" task has been broken down here into its component operations. Similarly, Figs. 3(B) and 3(C) show other typical level 3 functions.

Subsystem analysis

The number of matrix entries for each subsystem, as obtained from the function-subsystem matrix of Fig. 2, gives the rank order of the different locomotive subsystems reported previously by Sen and Ganguli (1982). The rank order shown in Table 2 gives important insight into the relative degree of utilization of each subsystem, and may be described as a sub-system utilization analysis. This provides indicators as to which controls and displays should occupy primary locations in the driver's cabin, which ones should occupy secondary spots, and so on. The matrix entries also provide quantitative values for weighting in priority allocation, and also for inputs to linear programming (LP) applications when using LP for optimizing the control panel layout.

A practical example may be cited. From Table 2, it may be seen that the most important functions are communications and braking, while the electrical and pneumatic systems are of minimal importance. Yet, in an actual running locomotive, the brakes are in a secondary position at the left, and there is no provision for communications with the external world (the query marks in the level 1 analysis in Table 1 may be recalled); while on the other hand, the traction motor current displays occupy the primary display location in front of the driver, and the pneumatic system displays are arranged with the brake pressure displays directly in the driver's line of sight.

The ranks correlate well with those of ROBINSON, *et al.* (1976) the correlation coefficient being 0.8. In both cases, the train brake system has been found to be of primary importance, while the engine and pneumatic systems are on the lowest level.

Table 3. Task complexity analysis.

Rank		Task	Matrix entries
1.		Take Train to Yard/Detach Locomotive	33
2.	(2.5)	Start Train	29
2.	(2.5)	Achieve Speed	29
4.		Check Locomotive	28
5.	(5.5)	Negotiate Curves	26
5.	(5.5)	Decelerate Train	26
7.		Stop Train	25
8.	(8.5)	Negotiate Gradients	24
8.	(8.5)	Negotiate Points	24
10.		Respond to/Transmit Signals	22
11.	(11.5)	Negotiate Neutral Sections	21
11.	(11.5)	Take Locomotive to Shed	21
13.	(13.5)	Move to Main Track	18
13.	(13.5)	Leave Main Track	18
15.	(16)	Take Loco to Statin/Form Train consist	13
15.	(16)	Monitor Loco Systems	13
15.	(16)	Sign Arrival Log	13
18.		Manage Auxiliary Systems	9
19.		Detach/Attach Shorts	8
20.		Check Train Consist	6
21.		Pass Trains and Equipment	4
22.		Obtain Proceed Signal	3
23.	(23.5)	Register with ATF	1
23.	(23.5)	Open Locomotive to Traffic	1

Figures in parentheses represent alternative ranking.
A higher number of matrix entries indicates greater task complexity.

Operations frequency analysis

By counting the number of entries for each operation, the operations were also ranked in a similar fashion. These ranks reflect the relative number of times each operation has to be performed, and hence the rank-order represents an operation frequency analysis. The full analysis is not given here, but the number of matrix entries can be read from Fig. 2. Communicating with the assistant driver was seen to be the most frequent activity, followed by those of braking the locomotive, applying tractive effort, monitoring speed, signals, *etc.* The least frequent activity was checking the lights and bulbs done while checking the locomotive at the start of the journey.

Task complexity analysis

Similarly, counting the entries horizontally gives an idea of how many operations are involved in each of the tasks, and may be taken as an index of task complexity. Table 3 gives the result of this task complexity analysis. The most complex task was that of taking the train to the yard and detaching the locomotive followed by starting the train and achieving the proper speed. The easiest jobs were opening the locomotive to traffic, and obtaining the 'proceed' signal. These complexity ratings correlate moderately ($r=0.63$) with those of ROBINSON *et al.* (1976).

RECOMMENDATIONS

The above analyses indicate that there are several areas where the present design needs modification. These include the following:

1) The brakes should be closer to the central area, preferably for the right hand operation. The direction-of-motion stereotype may be altered for faster and more efficient movement.

2) The horns, which have to be used very frequently, should be closer to the central area, so that they can be operated with minimum movement of the hand. Alternatively, the horn switch should be operable by foot depression or lateral pressure of the knee.

3) The present position of the speedometer makes it impossible, or at least very difficult, to see it when sitting. The speedometer should be directly in the driver's line of sight, perhaps between the two windshield panels. It is interesting to note that in locomotives where a new speedometer of a different shape is fitted as the older one went out of order, this is usually, perhaps inadvertently, done at the location mentioned (between windshields and in the line of sight). Drivers have reported their preference for the new location since it facilitates monitoring, and is suitable for both the driver and the assistant.

4) The traction motor current and voltage indicators should be moved into secondary locations to the left of the present position. Greater emphasis should

be placed on colour coding of the different areas inside indicators or displays as quantitative readings are required in very few cases only. The scales should also be so adjusted that for normal operational status, all the four pointers will be in a straight horizontal line. This will ease monitoring.

5) As the warning lights are quite far from the driver's line of sight, there should be an auditory back-up so as to draw attention to the fact that there is something wrong, after which the warning lights (which should be of the blinking type) can be looked at to discover the precise nature of the trouble. In fact, not all possible sensory channels are fully utilized in the design of locomotive displays, and the auditory system seems to be the least strained channel (JANKOVICH, 1972). Auditory warning of all crisis situations (*e. g.*, low brake pipe pressure, excess current in motors) will be useful for the railway locomotive driver, whose visual system is overloaded.

6) The majority of serious accidents appear to be associated with signals in three main ways. Firstly, signals are difficult to see due to bad weather conditions; secondly, it is claimed by the drivers that signals are often incorrect, or the aspect is changed at a time when it is too late to act on the changed aspect; and thirdly, some signals are disregarded or disobeyed. The second point is a source of discontent among drivers, especially in the case of allegedly late changed signals. To counter these problems, a form of continuous cab-signalling, or in-cabin displays of both forthcoming and past signals based on track circuits, is recommended, together with incorporating a recording device. Such a system is in use on the Italian State Railways' Settebello-class locomotives and in a number of other countries. A 'green' signal permitting maximum speed and a 'red' signal automatically causing application of the brakes may be displayed in the cabin, each corresponding to a high or a low track-circuit frequency. In between there may be frequencies corresponding to single and double 'amber' signals which permit the train to move at low speeds, activating the brakes if a given speed is exceeded. This system will ensure maximum operational safety, at the same time minimizing unnecessary slow movement. It is also 'fail-safe', as any defect or failure in the track-circuit automatically results in a 'red' signal. Full details may be found in KALLA-BISHOP (1972).

CONCLUSION

Before concluding, it must be pointed out that the above analysis has shortcomings. This is mainly due to the non-sequential part of the second-level analysis. It may be recalled that these 'tasks' may, during actual operation, be repeated any number of times and in differing permutations. This results in changes in the task-subsystem matrix, and thus also in the rank order. It is for this reason that the 'hear/sound horn' operation had a rank of as low as 17 in the operations frequency analysis, though actual observation showed that this was probably the most frequent activity. One way of attempting to rectify this anomaly is to observe and record (preferably by memo-motion cine-films) driver activities over a large number of journeys and to use the *mean number of* times each task is performed as a weighting to the matrix entry counts.

However, it cannot be denied that there are serious deficiencies in the design of the present cabins of the Indian Railways' locomotives. These defects make the working conditions unsafe, and open the door to 'human error' accidents. Therefore, the role of the man, the activities he has to carry out, and the physical and social environment in which he has to do this, all need to be given detailed consideration in order to optimize the Man-Machine-Environment relationship. Only in this way can efficiency and alertness be assured, along with both physiological and psychological well-being. It must be remembered that the proper design of the work-place is an essential part of operational safety and reliability.

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J. M. PATRICK

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The Ergonomics Society

The Society's Lecture 1983

Given at
The Churchill College, Cambridge, England, on 24 March

By RABINDRA NATH SEN

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APPLICATION OF ERGONOMICS TO INDUSTRIALLY DEVELOPING COUNTRIES

1. Introduction

This is perhaps the first occasion that a member of a Third World country has been invited to give the Ergonomic Society Lecture and have the opportunity of sharing experiences and ideas in this meeting of minds on a topic of his keen interest.

We may define ergonomics as the science, technology and art of man at work. When ergonomics is applied to industrially developing countries it may not follow the same course as that which was taken in the industrially developed countries. Disastrous effects may result when the technology suitable for a developed country (e.g. mining sulphur in a cold climate) is transferred to a developing country, such as Iraq, with hot environmental conditions without modification on the basis of anthropometric, climatic, socioeconomic, cultural and other differences (Sen 1980). Moreover, since technology originating in developed countries has to be sold, the pitfalls of application in the developed let alone in the developing world, on occasions, are poorly documented or not easily available making it well-nigh impossible to avoid recurrences of the same problems. However, much information may be gleaned from the knowledge accumulated over the last few decades on the application of ergonomics (Lippert 1968, Corlett 1968, Thompson 1972, Thring 1974, Chapanis 1975, Phoon 1976, Kogi 1977, Sen 1979, Manuaba 1979, Pinnagoda 1979, Wisner 1982).

Though exact situations may differ in different developing countries, similarities in respect of factors such as anthropometry, climatic, socioeconomic status, are sufficient to enable the application of ergonomics for progress and development. However, it is often difficult to fix priorities for factors in specific situations. Let us consider some of the important factors.

2. Differences in calorie intake

To enable workers to perform effectively, the required amount of calories and the right balance of nutrients must be provided. In developing countries, most workers support a number of non-earning family members (the extended family) on their limited income and, in consequence, may themselves suffer from under- and malnutrition. Many industries in developing countries have found it advantageous to give subsidized nutritional supplements to their workers in their canteen food instead of monetary incentives.

We started our work in industrial ergonomics in 1953 at a cotton textile mill in West Bengal. Our object was to identify levels of energy expenditure of workers performing different tasks, along with the determination of energy intake in 24 hours (Banerjee *et al.* 1959), with a view to improving workloads. We extended the work to other industries and to agriculture (Sen 1960, Sen *et al.* 1964 a, b, 1966, 1980, 1981, 1983). We found that energy expenditure for defined tasks was lower in India than for the same task in industrially developed countries. Furthermore, workers, especially those who were not organized, expended more energy than could be derived from the food they could purchase from their wages (Sen *et al.* 1978, Sen and Nag 1979, Kerkhoven 1962).

3. Anthropometric differences

The first systematic work undertaken by us in this field was to collect 30 different anthropometric measurements of 499 workers in 50 textile mills in Maharastra, in order to prepare design dimensions for textile machinery (Sengupta and Sen 1964). This was only a pilot survey which could not be continued elsewhere in India because of lack of funds. However, constants were suggested for the prediction of anthropometric dimensions from the body height or chest circumferences (Sen 1964). In another study, 16 anthropometric measurements were undertaken in 196 subjects (Sen *et al.* 1978) and 79 in a larger group in the east of India (Sen *et al.* 1977) to obtain data required for designing agricultural implements.

Equipment manufactured in developed countries is used by workers in developing countries, and there are limitations of funds and facilities for local collection of relevant anthropometric data, therefore manufacturers should not shirk their responsibility for collecting the required data from the localities to which their machines are exported. Furthermore, as purchasing departments in industry tend to lack ergonomic expertise, machines and equipment are largely selected on the basis of operating costs. Thus, the responsibility of matching man and machine must be shouldered by manufacturers. One way of attacking such problems involves instruction and training in ergonomics for engineers and designers of manufacturing companies. Ultimately ergonomics standards are required.

4. Postural differences

Several thousand years ago Indian sages realized the significance of the correct mode and maintenance of sitting, the most important and prevalent waking posture of the body. In their writings, they referred to the details of the methods of maintaining the correct sitting postures such as sitting cross-legged ('padmasana' in 'yoga') or squatting. Millions of oriental people have learned traditionally to sit restfully in postures which seem not only bizarre but also extremely uncomfortable to Westerners accustomed to sitting on chairs. There are considerable advantages in sitting on the floor in these postures.

(1) Considerable discomfort is felt when the air temperature at the head level exceeds that at the foot level by more than about 3°C. In tropical climates, not only is the floor usually cooler, but squatting also avoids this uncomfortable gradient.

(2) The venous return from the legs is significantly improved, consequently enhancing the blood volume available for cooling.

(3) It may result in the lower prevalence of varicose veins in Indians compared with housewives in England.

(4) A squatting posture is also used in the Indian W.C. and, what is more inguinal hernias are less prevalent in India; it is therefore suggested that one factor that may account for this finding is the support that this posture offers to the inguinal region during the increased abdominal pressure of defaecation.

(5) The desirable resting position of the hip joints is with 45° and not 90° flexion; it appears that in this posture thigh muscles are in a relaxed balance and the spine has a concave backwards curve.

(6) In many small-scale industries, squatting or sitting on the floor may be ergonomically advantageous because it avoids lifting heavy objects to a higher work surface and it is possible in that posture to use the legs and feet to hold objects (figure 1). Legs can also be used as armrests (figure 2).

(7) There is greater freedom for postural change than while sitting on a chair. Sitting on a 'chowki' (a low, big wooden platform with a thin cushion) offers immense scope for changing one's posture from sitting to semi-lying or even to a completely lying position, which is much better then the static posture imposed by sitting on a chair.

Observing indigenously designed machines, such as wood or sheet-metal lathes, grinding wheels or potter's wheels, being operated by workers sitting on the floor

Figure 1.

Figure 2.

Figure 3. Wood lat

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Figure 1. Holding objects with the feet while squatting on the floor.

Figure 2. Use of legs as armrests while working squatting on the floor.

Figure 3. Wood lathe being operated by squatting on the floor; both legs and hands are used.

(figure 3), it is easy to see the significance of such methods. As a large proportion of the world market covers societies where squatting or sitting on the ground predominate, it is unfortunate that up till now no modern machines have been designed to be used in this way.

5. Some social and cultural aspects

Many centuries ago various techniques and crafts were transferred from India to other parts of the world. Enough literature (Basham 1967) exists to show the profound influence of spiritual, emotional and aesthetic experiences on the oriental mind. Ancient India was a citadel of family-based cottage industries, arts and crafts, and as such traditional social, cultural and religious patterns create resistance to new technology and its import from developed countries.

Workers from different Indian states display a bewildering social, cultural and economic diversity in spite of the Indian tradition to create unity among diversities. This diversity enables the Indian to adapt himself more easily to alien traditions characterized by machines and working environments; adaptation may, however, be incomplete because some aspects of traditional social, particularly culinary, traditions are tenaciously maintained. It must be emphasized that it is not possible to obtain a complete picture of the culture of a community without living in its midst for years.

Michael Madhusudan Dutta, a famous Bengali poet and writer, wanted a thorough knowledge of English culture. He had the ambition to become a famous poet in English. To this end, he even married a European. In spite of it all, he was thoroughly dissatisfied when he found that he was still dreaming in Bengali, unable to dream in English. Similarly, innate social and cultural backgrounds will markedly influence the successful application of ergonomic principles. Thus, it must be recognized that it takes time and modification of established criteria before imported technology can be applied.

Peoples of many developing countries have a tradition of simple living but high thinking. In rural areas, especially, they wish to devote a greater part of their lifetime to stand and stare and to derive enjoyment from their work. This is in stark contrast to the more hectic lifestyle of the industrialized West characterized by the 'rat-race' and consumerism aimed at achieving an ever rising standard of living. Most Indians, for instance, use washed hands instead of cutlery at mealtimes avoiding the need for eleborate washing-up machines but making use, traditionally, of cold water, a desirable commodity in itself in a hot country but not in a cold country. Nobel laureate poet Rabindra Nath Tagore remarked 'When one takes food with knife and fork it is as if one is using an interpreter while making love, while when using fingers to put food into the mouth it is like courtship before marriage.'

Indians are predominantly right handed. Our preliminary study (Sen 1982, unpublished data) indicated that only 1% of the population is left handed, whereas this figure is considerably higher (10–20%) in some developed countries (Ainsworth 1983). This might have resulted from the social ethics of using the left hand for toilet purpose and for performing inferior types of work only, thus forcing the child towards right handedness. In consequence, the problems of designing right- and left-handed implements and tools are alleviated. In addition, in a country which is so predominantly right handed there may be different motion stereotypes. Once again it is important when recommending the transfer of technology that these considerations are taken into account to produce necessary product modifications.

An example from a different area is the safety poster. A poster design based on Western social and cultural norms depicting the diversion of attention by a scantily clothed lady had to be withdrawn from a factory in India because of the strong social objections against such obscenity. Safety posters to be effective, and indeed other forms of educational communications, must harmonize with the cultural and social norms of workers.

The practice of wearing only a short loincloth leaving the upper part of the body uncovered may seem to demonstrate poor socioeconomic status but is probably highly advantageous for thermo-regulation, minimizing heat stress in hot environments in which radiation heat load does not predominate.

It is interesting to note how local social customs or community habits may solve some problems; for example, in one Indian state it is customary, in a bus with no available seat, to sit on the lap of another passenger and so on in succession as the bus becomes progressively overcrowded. This

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The symbolism of colours may also differ from country to country, red, which indicates danger in Western countries, symbolizes auspicious events in India.

The art of Asian developing countries emphasizes curves or non-linear forms, whereas in the West rectilinearity predominates in geometric forms. These contrasts should be taken into consideration when developed countries export their goods to the developing world.

6. Agricultural and unorganized workers

Unorganized workers, including those in agriculture, have many problems which could be solved using ergonomic principles but unfortunately very little is done. In our own studies on agricultural workers, we found more objective methods for the scaling of workrate and efficiency, based on biological parameters (Sen 1982 b). Moreover, we made improvements in the design of simple implements such as the plough, sickle, shovel, spade and hat (Sen 1979, Sen and Bhattacharyya 1976, Sen and Pradhan 1978, Sen and Mazumdar 1978) (figure 4).

We also succeeded in using ergonomic principles to improve the working conditions of artisans whose job involved the use of conch-shells to make ladies' jewellery. We used work-and-time study to compare existing manual methods with those used to make bangles by machine (Sen *et al.* 1975, 1976 a). We extended our study to investigate the problem of achromatopsia (colour blindness) in these workers (Pickford *et al.* 1978, 1979, 1980, Sen *et al.* 1976 b). Our study of unorganized porters who carry loads well above the recommended weights of up to three times their own body mass, suggested rationalization of work and proper work–rest cycles (Sen and Nag 1975).

Our studies of tea-leaf plucking (Sen and Chakraborty 1979, Sen *et al.* 1980, 1981, 1983) indicated that the application of ergonomic principles resulted in: (i) a reduction of workload and improvements of work methods, (ii) a recommendation for the selection of bush dimensions, (iii) the design of a new ventilated hat and (iv) an improvement in the selection of workers. We were able to show, for instance, that simple monochromatic (red or green) glasses could help female workers distinguish the desirable young shoots from the dark background, resulting in an increase in plucking rates (Sen *et al.* 1980), with improvement of quality.

In India, which has a labour-intensive economy and a natural mistrust for automation, the application of ergonomics could ensure that individuals are utilized efficiently without exploitation, avoiding detrimental health consequences and yet proving advantageous to the system. While labour may often be the most prolific resource, to waste it is to add expense, on the other hand, the use of muscles to perform moderate levels of physical work does keep individuals fit (Sen *et al.* 1973).

Figure 4. Improved design of a shovel in operation.

7. Small-scale and cottage industries

Many traditional crafts are disappearing from developing countries as a result of rapid industrialization. It is important that efforts are made to preserve traditional production in the so-called cottage industries.

In analysing the impact of strained industrial relations on the sickness of industry, it clearly emerges that some units could sustain a number of workers on relatively low wages. When the level of wages started rising by collective bargaining or by virtue of neutralization of the larger pay-packet by the increased cost of living, the productivity element becomes very important and unless productivity rises *pari passu* with the rise in wages, the economics of the scale of production cannot be maintained. While large- and medium-scale industries have some resilence to bear the higher wage cost, small establishments gradually disappear from the scene.

In developing countries one of the important problems is to achieve cheap energy sources. In India a huge amount of wood fuel is used. In the small-scale production of plywood, the cost of energy is critical and solar radiation is used to dry the wood shavings. This requires a great deal of physical work in spreading and collection but the application of an ergonomic work method makes for enough efficiency to make the method competitive with other arrangements of drying wood (figure 5), furthermore, larger number of workers are employed and it is unneccessary to purchase costly ovens.

8. Design ergonomics

In India, today, 75% of urban and 98% of rural freight moves by bullock-cart, more than 90% of all urban transport is non-motorized. Improvement of the design of such a transport system is a challenge to ergonomists, bearing in mind that mere motorization may be prohibitive because of the increasing cost of oil-based fuel.

Even motorized transport, however, does need attention; public buses especially the double-deckers of urban areas, are copies of London buses. They were originally designed for use in cold climates and unmodified they are, therefore, unlikely to be suitable in heat. Local buses, on the other hand, run by private owners, are more appropriately designed with wooden roofs and drop windows of considerable area. There is thus much scope to improve the design of the former (Sen and Nag 1973). There are also enough suggestions for reducing overcrowding of buses and trains (Sen and Nag 1974). In a related field, studies on the design of railway-engine cabs suggested many ways for improvement (Sen and Ganguly 1982 a, b) to make them fit for local Indian conditions.

Design of (pedal-operated) cycle or hand-pulled rickshaws (figure 6) may be improved by the judicious application of ergonomic principles (Sen and Basu 1977). Rickshaws have certain overriding advantages—they do not use fossil fuel, nor pollute the air, they can, among other uses, become emergency ambulances or be readily used for load

Figure 5. Use of solar energy to dry wood shavings in plywood industry.

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Figure 6. Design of pedal-operated cycle-rickshaw.

Figure 7. Use of rickshaw in water-logged streets of Calcutta during the monsoon.

Figure 8. Indigenous designs of bamboo ladder and head gear by building construction labourers.

carrying, and they become the mode of carrying passengers during the monsoon in the water-logged streets of Calcutta (figure 7), when more sophisticated autorickshaws are immobile.

On another tack, the design of implements such as the shovel (Sen and Bhattacharyya 1976) (figure 4), spade (Sen and Pradhan 1978, Sen *et al.* 1979) and sickle for agricultural work, and beater, pick-axes and ballast rake for the maintenance of railway tracks, are examples of improvements made with designs based on ergonomic principles. These modifications may help improve productivity. Head gear made up of a gunny bag pad used by building construction labourers and home-made bamboo ladders (figure 8) are examples of simple, low-cost indigenous designs adapted to the situation through naturally evolved applied ergonomics.

9. Improvement of working conditions and safety

Optimal indoor climatic conditions are most efficiently achieved by relying on structural features of the building itself, introduced at the design stage. This approach may obviate the need for any mechanical device, such as fans or air conditioning, to control conditions (Sen 1982 a).

Thermal stress and workload studies were performed in a soap factory (Sen *et al.* 1964 b), and it was found that by simply opening a portion of the wall, allowing natural cross ventilation, very uncomfortable conditions were transformed to become very confortable. Similar studies in textile, steel (Sen *et al.* 1964 a, 1966) and jute mills (Sen and Mazumdar 1982) have resulted in considerable insight into ways of improving workload, thermal stress and safety. Simple observations can lead to profound changes. In many situations it was observed that bad working conditions were produced by windows being hinged on the wrong side so that when opened air movement was deflected outwards; simply reversing the hinges markedly improved the natural ventilation (Sen 1982 a).

Noise may produce hearing loss and lead to deterioration and increase in physiological costs (Gupta *et al.* 1965, Sen 1967). Noise reduction is expensive, instead low-cost ear protectors could be used. When noise is distracting and workers have to perform mental work with minimum error, they can be trained to concentrate, not allowing annoying noises to reach consciousness. In the social and cultural background to which Indian workers belong, such training can easily be carried out with benefit to the worker and to his work (Sen 1967).

The scale of the use of human resources in developing countries is enormous and it must be obvious that very small improvements in working conditions, implements, tool design or work methods can lead to large benefits. In India, the majority of industrial workers are recruited from agriculture, their high level of absenteeism at particular seasons may be explained by their dual life—attending at the appropriate season to their agricultural work in the villages, returning only to their abnormal industrial occupation during the lean months. Improvement in shift-work systems (Sen and Kar 1978, 1979, Sen *et al.* 1982) is necessary for betterment of the quality of working life.

One further problem faced by the people of so many developing countries, such as India, is the menace of pests such as mosquitoes. Can ergonomics help to show a way to eradicate mosquitoes applicable to a developing country? Conventional methods, such as the application of pesticides, may bring their own problems of pollution and the mosquitoes becoming immune, moreover, they are expensive. The menace of mosquitoes is so great that it is estimated that every year in India about Rs.10 million ($1 million) worth (at blood bank price) of human blood is sucked, furthermore the misery and deaths resulting from mosquito-borne diseases, such as malaria, filaria and encephalitis, are colossal. Fish such as *Labister reticulatus* and *Gambasia affinis* eat mosquito larvae and are used in eradication, but their utility is limited since no such fish can be cultivated in the small pot-holes or ditches which are the breeding ground of many mosquitoes. As an ergonomist in a developing country I often pondered this question trying to devise simple and inexpensive solutions. I observed that a man in a heavily infested locality, inside a mosquito curtain, in the dark, attracting the insects (figure 9), can squash them between the two layers of the curtain; thus, using a fraction of his capacity for a few minutes a day he can eradicate between 0·03 and 0·1 million mosquitoes per month. Maybe this can be a fairly efficient method of control in a developing country which has ample human resources. Such a method makes use of the advanced knowledge of mosquito behaviour and physiology

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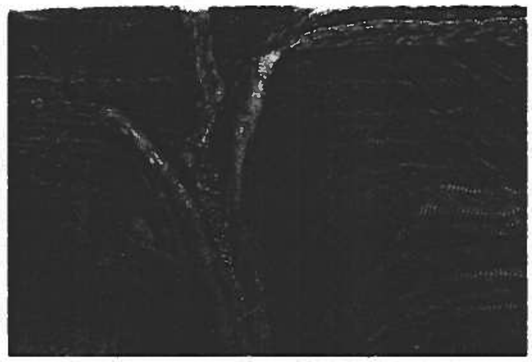

Figure 9. Attracting mosquitoes and killing them manually.

such as their swarming, photophobia, and their infrared sensors. Such a simple idea allows scope for further improvement, for instance, a high-speed table fan placed outside the mosquito curtain not only provides good ventilation but also kills hundreds of mosquitoes.

10. Training

In India, as elsewhere, the education system has come under severe criticism because of its perceived failure to make adequate links between education and work. The time may now be ripe to examine whether our education system has helped to improve living conditions in general or has merely created a largely unproductive consumer class. The school of tomorrow in a developing society could act as a centre of exchange for information on prevalent social practices from different parts of the country and be the instrument to make the choice of the most effective ones for the particular community it serves. It has been suggested that like our traditional mode of training, imparted by craftsmen to their children, training programmes should be organized in such a way that local craftsmen (carpenter, mason, tailor, weaver, workshop mechanic, etc.) can be used, on a part-time basis, to train children in school in their respective skills. A substantial part of the resources, such as those from the National Council for Educational Research and Training, could be used to prepare teaching aids and materials to be used by teachers and communicators for such mass education. However, such apparently radical concepts are not easy to get over to the administrators of our educational system.

In a country where 80% of the people are engaged in agriculture, less than 5% of scientific and technical personnel specialize in this subject, and of that 5%, a bare 10% are engaged in research and development. Less than 1 in 100 million in India have the chance to specialize in ergonomics at postgraduate level. It is, therefore, important that the training programmes for workers (agricultural and industrial), trade union officials, managers and executives, government officials and the common man are formulated to have suitable links with reality making optimal use of our precious and rare expertise for specialized fields. Mass media could be used much more effectively to bring awareness and application of ergonomics to ordinary people.

Many of the courses in science and technology in developing countries are started on borrowed curricula. Moreover, various teaching institutions are supported by Western countries whose technology is capital-intensive and labour-saving. These curricula and the institutions are naturally heavily influenced by that particular mode of operation. As a result, they do not have much relevance to real-life situations. Programmes for education on ergonomics with special reference to developing countries should be started in schools. The Schools' Ergonomics programme in Scotland, as suggested by Andrews and Kornas (1982), would probably have to be substantially modified to make it suitable as a guide for Third World schools.

Ergonomics may have an important part to play in overcoming language barriers in technical training; for instance, instructions could be effectively presented in a symbolic language, particularly for complex devices such as public telephones or ticket machines which are often presented to people who lack any technical background.

11. Conclusions and recommendations

Ergonomics in developing countries may be applied in two ways: (i) fast, short-term or (ii) longer-term effects. For short-term application the following areas need attention:

(1) Design of mass low-cost housing, schools and hospitals to replace existing designs, both for rural and urban areas.
(2) Design of low-cost personal and public transportation systems for rural and urban areas and the concurrent improvement of existing systems such as bicycles, rickshaws, hand-carts, bullock-carts, wheelbarrows, buses, trams, railway coaches and drivers' cabins, to make then suitable for local conditions.
(3) Improvement of the design of agriculture and industrial tools and implements such as ploughs, sickles, threshers, water lifting arrangements, shovels, spades, pick-axes, beaters, ballast rakes, etc., and personal protective equipment such as hats, gloves, work wear, etc.
(4) Design improvements of consumer products to ensure increased reliability and ruggedness and to facilitate repairs in cases of failure.
(5) Education through mass media heightening awareness of some simple concepts and applications of ergonomics aimed at improving everyday life.

The following ideas, are suggested with the longer term in view:

(1) Surveys should be undertaken to establish anthropometric, sensory and motor ability norms of local populations to include sex and age differences. Habitual activities in different areas of the country of different ethnic groups should be assessed using the same standardized methods.
(2) Research to develop heat-stress indices suitable for use in India should be undertaken and, more importantly, there needs to be greater emphasis on examining how managers at local level could apply them in the field.
(3) Ergonomics resources for proper work organization to eliminate and reduce the deleterious effects of various types of monotonous tasks and shift work should be undertaken.
(4) Long-term research should be initiated to establish threshold limits values of toxic substances under the particular work conditions in India.
(5) A start should be made to apply the fruits of ergonomic research to small undertakings, to unorganized workers and co-operative organizations and communities such as fishermen, blacksmiths or potters, who still make up a large part of India's work force.
(6) Known safeguards should be applied for improving safety to reduce accidents. Attempts should be made to design standardized signals and symbols to be used in instructions for day-to-day operations in industry and agriculture, which can be applied in spite of low literacy levels, diverse traditions, socioeconomic status, culture and languages.
(7) The researches recommended here, with their long-term aims, might be co-ordinated in a single institute, with the advantage of long-term stability and a strategic rather than a tactical view point. Furthermore, such an organization would serve to concentrate scarce expertise.

It is heartening to learn that at Luleå University in Sweden, an Institute of Ergonomics for Developing Countries has been established and that the International Labour Organisation has also taken some initiatives in this field. These are portents for the future signalling progress for the application of ergonomics in the aid of development.

As members of industrially developing countries, our choices and possibilities are severely constrained and within these inescapable limitations we have to do the best we can, and we shall always look to industrially developed countries for all the help that they can offer.

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To: cottura@cnam.fr
Subject: letter
From: rnsen@cubmb.ernet.in (Rabindra Nath Sen)
Date: Tue, 12 Dec 95 18:49:10 IST

Dear Prof.Dr. Wisner,
Today I received your kind Email letter dated 7th.December, 1995 which has been so kindly recovered by Prof.Thakur as the address of my email name was given wrong "fnsen" instead of "rnsen". I think your original email has been returned to you. I am also not sure whether your Email address is correct or not. However, I would find it if this email is not returned. We are very much grateful that you have so kindly agreed to deliver the Keynote address as well as act as a Foreign Faculty in the Pre-Symposium workshops. Your topics are also very suitable. We would discuss with the members for their efforts in extending all the possibilities of local hospitalities we could extend. I would write to you by Email or by Air Mail in detail. With Seasons' Greetings and kindest personal regards,
Yours sincerely,
Robin, 12th.December,1995,

CONSERVATOIRE
NATIONAL
DES ARTS
ET MÉTIERS
ERGONOMIE ET
NEUROSCIENCES
DU TRAVAIL

Paris, December 7, 1995

Prof. Dr. R.N. Sen, D.Sc.
Professor and Head of
Ergonomics Laboratory
HB - 260, Sector - 3, Salt Lake City
Calcutta, 700 091 India
E-Mail

Dear Professor Sen,
Dear Rabindranath,

Since I wrote to you recently, I have received two documents which answer my questions.

The Registrar of the University of Calcutta sent me Mr Samit Kumar Mitra's thesis. I shall try to read it quickly and send the report requested to the Registrar and yourself.

I also received an official invitation to present one of the Keynote Addresses to the Symposium that your are organizing in New Delhi on November 25 to 28, 1996. You also suggested that I should take part in the pre-Symposium Workshops. I am very flattered by these two invitations and am delighted to accept.

As regards the themes I could tackle, in the Keynote Addresses my first reaction would be to mention the problems encountered and the successful development of ergonomics in industrially developing countries, especially those, like India, which have developed rapidly and are sometimes referred to as New Industrialized Countries to demonstrate the power and originality of Indian development in which your role has been - and still is - predominant.

Along the same lines, but using a different method, I could dedicate a workshop to technology transfers seen from the anthropological angle.

However, I am not sure that my suggestions are right; I think it would be more reasonable for you to take a look at the texts I published recently in English so that you can make the choice yourself.

You mentioned the financial problems raised by such a participation. Thank you for whatever you can manage, without creating a burden on the financing of an International Congress that is always difficult.

I am sure I can pay my flight ticket and possibly my accommodation costs without any difficulty. As regards the inscription fee, see what you can do. Perhaps this decision could be left until I arrive in New Delhi.

I look forward to meeting you again and wish you all the best in this exciting but difficult initiative.

Truly yours.

A. Wisner

N.B. In another mail you will find some 15 texts which partially reflect my recent activity. There is not always an English version of what I write.

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ERGONOMICS LABORATORY

DEPARTMENT OF PHYSIOLOGY

UNIVERSITY OF CALCUTTA

From :
Prof. Dr. R. N. Sen, D.Sc. (Cal)
Professor and Head, Ergonomics Laboratory
Please Reply to : HB - 260, Sector - 3, Salt Lake City,
Calcutta - 700 091 INDIA
E-Mail No. : rn sen @ cubmb. ernet. in

University Colleges of Science, Technology & Agriculture
[redacted]
INDIA

Ref. No. PHY/ERG/RNS/ ISE-OH-SE/95

Dated 20th Oct., 1995

Dear Prof.Dr.Wisner,

* I am enclosing herewith the official letter of invitation to you for kindly delivering the Keynote address at the 2nd ISE-OH-SE.

I am also to request you kindly to act as a Foreign Faculty in the Pre-Symposium Workshops to deliver one or two lecture-cum-demonstrations on the topics of your choice to the industrial participants.

We have sent by registered post the complimentary copy of the full proceedings of the 1st ISE-OH-SE as your personal copy. Kindly acknowledge the receipt of the copy.

* I am enclosing a flyer for the full proceedings (ISBN 81-900508-0-X) of the 1st ISE-OH-SE which has already been printed as a 255 + x pages of A4 size hard bound volume with a price of US $ 35.00 or equivalent without the cost of postage. Will the Librarian of your Organisation be interested in placing an order for this book entitled "Occupational and Environmental Ergonomics", at an early date ?

As one of the Members of the body of the International Scientific Advisory Committee of the 2nd ISE-OH-SE, will you kindly send advices and suggestions to make the ensuing Symposium and the Workshops a grand success ?

With kindest personal regards and very happy Vijaya and Dipawali Greetings to you,your family and colleagues,

Yours sincerely,

(R.N. SEN)
Hony.Secretary General,ISE-OH-SE

* Enclo : as above.

Prof.Dr.Alain Wisner
Emeritus Professor
Laboratoire d' Ergonomie
Conservatoire national des arts
41, Rue Gay Lussac
F-75005 Paris,
FRANCE.

UNDER CERTIFICATE OF POSTING.

SECOND
INTERNATIONAL SYMPOSIUM ON ERGONOMICS,
OCCUPATIONAL HEALTH, SAFETY AND ENVIRONMENT
(ISE-OH-SE)

PHY/ERG/RNS/ISE-OH-SE/95 Dated : 7th October,1995.

Prof.Dr.Alain Wisner
Emeritus Professor
Laboratoire d' Ergonomie
Conservatoire national des arts
41, Rue Gay Lussac
F - 75005 Paris, France.

Subject : Invitation to deliver Keynote/ Plenary papers at the 2nd ISE-OH-SE to be held in New Delhi in November,1996.

Dear Prof.Dr.Wisner,

The Indian Society of Ergonomics (ISE) and the International Ergonomics Association (IEA) are hosting jointly the Second International Symposium on Ergonomics, Occupational Health, Safety and Environment (ISE-OH-SE) in New Delhi from 25th to 28th November, 1996, which would be organized by the Defence Institute of Physiology and Allied Sciences (DIPAS). It is the most important meeting in this area in Asia. In addition to attracting high quality scientific papers, this always has been a prestigious event. It is the intention of the Organizing Committee to sustain and perhaps improve the performance of this International Congress.

It is with this intention that the Organizing Committee have decided to invite selected leading scientists around the world to deliver Keynote/Plenary papers to set the tone of the Congress. Since you are an internationally recognized scientist, I, the Secretary General of the Organizing Committee, have the pleasure of inviting you to deliver a paper on your selected topic.

As is the case in most of the conferences, the funds are extremely limited. Although we are not in a position to offer you financial assistance towards Air travel, we would provide you some local hospitality. I sincerely hope this will not prove to be a deterrent for you and funds will be available from your local sources. We wish you will be able to join us for the Symposium and share some of your research experiences. Will you kindly send the title of your Keynote/ Plenary paper for the Symposium, at your earliest ?

We also hope that you would encourage many of your colleagues to present papers at this Congress to make it a grand success. We look forward to your positive response and to have an opportunity to interact with you during your visit. Your helpful advice regarding the Symposium will be most welcome.

With kind regards,

Yours sincerely

(Prof.Dr.R.N.Sen)
Hony. Secretary General
Organising Committee (ISE-OH-SE)

Secretariate:
HB - 260, Sector - 3,
Salt Lake City,
Calcutta - 700 091, INDIA.
E-Mail : rnsen@cubmb.ernet.in

List of Papers, Monographs and Books of Prof.Dr. Rabindra Nath Sen, B.Sc(Hons), M.Sc.,D.Sc.,FIIST, Professor,Department of Physiology & Head,Ergonomics Laboratory,University Colleges of Science,Technology & Agriculture,Calcutta University, 92,A.P.C. Roy Road, Calcutta - 700 009, INDIA.

...

(Mailing Address : ~~11A,Mohan Bagan Lane,Calcutta - 700 004,INDIA~~)
(HB 260,Sector-III,Bidhannagar,Calcutta-700 091, INDIA).

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BRIEF BIO-DATA OF PROF.DR.RABINDRA NATH SEN, DSc., FIIST

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II. Designation	:	University Professor
III. Present Address	:	Ergonomics Laboratory Department of Physiology University Colleges of Science, Technology and Agriculture 92,Acharyya Prafulla Chandra Road Calcutta - 700 009 INDIA.
IV. Permanent Home Address	:	HB-260,Sector III Salt Lake City Calcutta - 700 091 INDIA.
V. Date of Birth	:	1st February, 1931 (Matriculation Certificate)
VI. Marital Status	:	Married; One child

VII. University Examinations passed :

(i) Matriculation (Calcutta University) in 1948 in 1st Division with distinctions (about 80% marks) in Mathematics, Mechanics, Geography & Sanskrit.

(ii) Intermediate Science (Calcutta University) in 1950 in 1st Division with distinction in Physiology as one of the subjects.

(iii) Bachelor of Science (Honours) (Calcutta University) in 1952 with Honours in Physiology; subsidiary subjects were Physics and Chemistry.

(iv) Master of Science (Calcutta University) in 1954 in 1st Class, stood 2nd (in order of merit), received University Prize; had thesis on "Studies on Energy Metabolism" in lieu of Special Paper (Vth paper).

(v) Doctor of Science (Calcutta University) in 1961, Thesis entitled "Studies on Certain Aspects of Energy Metabolism in Indians" - (2nd receipient of the D.Sc.Degree in Physiology in Calcutta University).

VIII. Teaching add Professional Experiences :

(i) Working as a Professor and the Teacher-in-Charge of the Specialisation on Ergonomics, Department of Physiology, Calcutta University from 1983.

(ii) Guiding research students working for the M.Sc., M.Phil. and Doctorate degrees in Physiology/Ergonomics & Work Physiology/Environmental Sciences from 1970 to the present time.

(iii)Working as an Examiner in D.Phil.(Sc.),Ph.D.degrees in Physiology/Ergonomics of the Calcutta University and other Universities in India.

(iv) Working as Examiners in BSc(Hons) & MSc degrees in Physiology, B.Tech. & M. Tech. degree in Applied Physics of the Calcutta University since 1961 & 1973 respectively.

(v) Working as an Editor of the Journal of Human Ergology, Centre for Academic Publications, Japan, from 1978; as an Overseas Editor of the Journal of Applied Ergonomics, Butterworth-Heinemann, U.K. from 1983; and as a member of the Editorial Board of the Journal of Industrial Ergonomics, Elsevier, The Netherlands, from 1985; International Reviews of Ergonomics, Taylor & Francis, U.K., from 1987; and Overseas Correspondent of the Journal of Ergonomics,Taylor & Francis,U.K., from 1986; worked as an Editor of the published Proceedings of several International Symposia.

(vi) Worked as a Reader & Teacher-in-Charge, Ergonomics Laboratory, Dept.of Physiology, Calcutta University from 1970 to 1983 and as Head of the Dept. from July 1981 to August 1983.

(vii) Worked as a Visiting Faculty Member in the Department of Ergonomics & Cybernetics, University of Technology, Loughborough, Leicestershire, England from 27th October,1967 to 27th October,1970, on lien and taught U.G.(BSc,B.Tech.) and P.G.(MSc, M.Tech.) students in Ergonomics and Human Biology.

(viii) Worked as a Teacher in Factory Inspectors' Training Courses, and other training courses for Industrial Engineers, Physicians, Supervisors, Labour & Welfare Officers and Management, as an Assistant Chief Adviser Factories,Assistant Director and Head, Industrial Physiology Division in the Central Labour Institute,Bombay from 1st May, 1962 to 26th October, 1967; teaching post-graduate students,in Biophysics, Work Physiology & Ergonomics/Sports & Exercise Physiology and M.Tech.students on Advanced Instrumentation(Bio-Technology) from 1972.

(ix) Worked as a Lecturer and an Assistant Professor of Physiology (both under-graduate and post-graduate courses in Human Physiology) in Presidency College,Calcutta from 1st February, 1958 to 30th April, 1962.

(x) Worked as the Course Director in different Intensive Advanced Study Courses, Orientation Courses,In-house Factory Training Programmes, etc., on Ergonomics,Work and Sports Physiology; conducted different Workshops on Ergonomics, Occupational and Environmental Physiology in India and abroad.

(xi) Worked as an Examiner in BSc(Pass) and BSc(Hons) degrees in Physiology of the Calcutta University from 1958 to 1961.

(xii) Worked as the Recorder in 1974 & 1975 and the President in 1979 for the Section of Physiology of the Indian Science Congress.

(xiii) Worked as the Hony. Treasurer from 1971 to 1979 and worked as the Hony.General Secretary & a member of the Editorial Board of the Physiological Society of India from 1979.

(xiv) Worked as a Consultant/Adviser of Ergonomics in Ford Motor Co., U.K., General Post Office, U.K., ILO, Geneva; Guest Kins Williams, Calcutta Electric Supply Corporation and various factories in Calcutta.

(xv) Acted as an ILO Expert in the International Conference on Humanising Work Environment held in Bangkok in 1976 and also in the ILO/WHO Multi-disciplinary Mission in Iraq in 1978 and as a Resource person in the ILO Workshop in Singapore in 1982.

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(xvi) Acted as a member of the Panel of Experts on Ergonomics, Department of Science & Technology, Government of India and also in the National Committee of Indian National Science Academy (INSA), New Delhi, for International Union of Physiological Sciences (IUPS) for two consecutive terms of three years each.

(xvii) Only Indian regular member representing the International Council of Physical Fitness Research since 1971.

(xviii) Only Indian Member to the Technical Committee on Ergonomics in the Asian Association of Occupational Health, Singapore since 1980.

(xix) Worked as the Scientific Convener of the National Seminar on Ergonomics held in Calcutta in 1972 and the International Satellite Symposium on Work Physiology and Ergonomics held in Calcutta in 1974; as the Hony. Secretary General of the International Symposium on Applied Physiology & Ergonomics, held in Calcutta in 1983, and also of the International Symposium on Ergonomics, Occupational Health, Safety & Environment (ISE-OH-SE) held in Bombay, in 1991.

(xx) Member of the Ergonomics Society, UK; The Indian Society of Ergonomics; The Physiological Society of India; Fellow of the Institution of Instrumentation Scientists & Technologists; Member of International Commission of Occupational Health, Geneva; International Social Security Association (ISSA), France; South East Asian Ergonomics Society(SEAES), Singapore; Indian Society of Biomechanics; Indian Science Congress Association; The Society of Animal Physiologists of India (SAPI).

IX. Research Experiences :

(i) Published about one hundred thirty scientific papers and books and guided about two hundred twenty five short-term and long-term research projects.

(ii) Attended International Conferences/Symposia organised by UNESCO, ILO, WHO, NIOSH, IEA and other International Organizations in UK, USA, Canada, France, Germany, Netherlands, Czechoslovakia, Sweden, Switzerland, Japan, Sudan, Singapore, Thailand, USSR, Indonesia, Hongkong, Iraq, Australia, etc., to present papers on Ergonomics, Occupational Health and Safety and chaired different scientific sessions.

(iii) Worked with Dr.P.R.M. Jones from U.K. in the study of International Biological Programme in New Delhi in 1972, with Prof. R.W. Pickford from Glasgow University, U.K., on Colour Vision and Ergonomic Study on Conchshel artisans in Bishnupur, West Bengal, in 1975, with Dr. R. H. Harding from UK, on ergonomic study on agricultural workers in Bihar & Darjeeling in West Bengal in 1979 - 80 and with Dr.K.Kogi and Dr.G.W.Crockford, ILO Experts from Japan and UK on Development of Special Work Clothing in Hot Environment in 1980 & 1984.

(iv) Worked with Prof. W.F. Floyed as a visiting Post-Doctoral Research Fellow in the Department of Ergonomics & Cybernetics, University of Technology, Loughborough, Leicestershire, England, from 27th October, 1967 to 26th October, 1970.

(v) Worked as the Indian Counterpart with Dr.K.Podlesak (Czechoslovakia), ILO Expert in Industrial Physiology and Industrial Hygiene in 1966 and 1967.

(vi) Worked as the Principal Investigator and the Officer-in-Charge of a research scheme entitled "Studies on Physiological Factors Limiting Work Output of Indian Workers" under the Indian Council of Medical Research, New Delhi, from 1st June,1965 to 30th September, 1967.

(vii) Worked as the Head of the Industrial Physiology Division of the Central Labour Institute,Bombay and guided research in applied physiological problems in Indian industries, from May, 1962 to 25th October, 1967.

(viii) Worked as the Indian Counterpart with Dr.J.G.Fletcher(USA), ILO Expert in Industrial Physiology in 1964.

(ix) Worked as the Indian Counterpart with Prof. E. H. Christensen (Sweden), ILO Expert in Work Physiology in 1962.

(x) Independent Research Work while working as a Lecturer and Assistant Professor of Physiology in Presidency College, Calcutta.

(xi) Worked as an Assistant Research Officer in the scheme "Studies on Energy Metabolism under Indian Council of Medical Research in Presidency College, Calcutta, from 1st July, 1957 to 31st January, 1958.

(xii) Worked as a Research Assistant in the same scheme from 1st April, 1955 to 30th June, 1957.

(xiii) Worked as a Laboratory Assistant in the same scheme from 1st April, 1953 to 31st March, 1955.

X. Important National and International Awards Received :

1. Awarded the Distinguished Foreign Scientist Award of 1991 by the Human Factors Society, USA, for Outstanding Contributions in Ergonomics/Human Factors field.
2. Awarded a Visiting Professorship in the Institute of Conservatoire National des Arts at Metiers (Paris Technical University), France in 1990.
3. Awarded Visiting Professorship in the University of Wisconsin, USA and at Milwaukee University in 1990.
4. Awarded the British Council Visitorships in England in 1983 and 1990.
5. Awarded the prestigeous Ergonomics Society Lectureship, nominated by the Royal Society, UK in 1983.
6. Received the Firestone Award from the Society of Industrial Medicine for the best paper of the year pubished in the Indian Journal of Occupational Health, in 1966.

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Research Projects Reports on Ergonomics under the Initiation, Guidance and Supervision of Prof.Dr.R.N.Sen,BSc(Hons),MSc, DSc, FIIST, Ergonomics Laboratory,Department of Physiology, Calcutta University, 92, A.P.C.Road, Calcutta-700009, INDIA

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Human Factors Society

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**HFS DISTINGUISHED FOREIGN COLLEAGUE AWARD
PRESENTED TO RABINDRA NATH SEN**

SANTA MONICA, CA -- The Human Factors Society honored Rabindra Nath Sen with its 1991 Distinguished Foreign Colleague Award during a special ceremony at the HFS 35th Annual Meeting. The meeting took place September 2-6, 1991, at the San Francisco Marriott Hotel, site of the awards ceremony.

The award recognizes a non-U.S. citizen who has made outstanding contributions to the human factors/ergonomics field. Sen is professor and head of the Ergonomics Laboratory in the University of Calcutta Department of Physiology and has been instrumental in bringing ergonomics teaching and research to India. His pioneering contributions to the introduction of appropriate work physiology to India have helped to mitigate environmental hazards, and recently he broadened his perspectives to include the transfer of ergonomics to developing countries. He has been a mentor to his many students and colleagues in India and has managed to advance ergonomics despite enormous economic disadvantages. Sen is ex-president of the Section of Physiology of the Indian Science Congress, former honorary general secretary of the Physiological Society of India, and present honorary general secretary of the Indian Society of Ergonomics. His contributions have earned him the title of "father of ergonomics" in India.

* * *

The Human Factors Society is a multidisciplinary professional organization of almost 5000 persons in the United States and throughout the world. Its members include psychologists, designers, and scientists, all of whom have a common interest in designing systems and equipment to be safe and effective for the people who operate and maintain them.

INDIA
(divan)

Consommation alimentaire et poids individuels des différentes castes d'un village de l'Inde

Swaminathan ... Indian J. Med. Research nov 1960

Caste	Revenu (Rs/personne/mois)	Consommation kcal/j	Poids moyen des adultes (kg) hommes	femmes
Pêcheurs	6,5	1580	48	41
Harijans (caste inférieure) (fils de Dieu - intouchables)	7,5	1940	46	40
Divers	10	1960	48	41
Agriculteurs	8	2240	49	41
Brahmins & Vaisyas	18	2720	51	45

INDIAN
AUTHORS
OTHER THAN
ANTHROPOMETRY

Sam White
Dec 96

INDIAN PHYSIOLOGISTS

15.7.86

24

SEN. ~~[illegible]~~ and OTHERS

without NAG and GOSWAMI

without Anthropometry

KULKARNI V.P., DUTTA S.P. (1980)

Research report on ergonomic norms in process design

NATIONAL INSTITUTE FOR TRAINING IN INDUSTRIAL ENGINEERING
BOMBAY

Maximal pulling and pushing forces

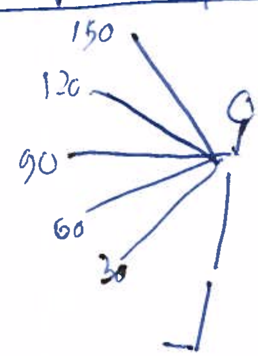
20 subjects ~~male~~ Age 23 y
Height 160 cm
Weight 45 Kg

NO REPRODUCTION

	ANGLE	30	60	90	120	150
PULL	RIGHT H.	15,5	8,7	7,5	11,4	22,2
	LEFT H.	15,3	8,1	7,05	11,6	21,3
	BOTH H.	19,7	9,1	8,3	14,1	28,5
PUSH	RIGHT H.	8,5	5.5	5.0	8,6	18.4
	LEFT H.	8,2	5.0	4.0	8.0	18.3
	BOTH H.	10.0	6.0	6.3	11,1	22.0

3'' in ~~coronal~~ sagittal plane

Max value abduction in coronal plane



The ergonomic examples are not very convincing.

The study is superficial

TWO HANDS RESULTS IN OTHER COUNTRIES

(ELBOW ALWAYS AT 180°)

PULL

ANGLE	DAVIS AND STUBBS ~~NETHERLANDS~~ (UK)	DON CHAFFIN (USA)	KELLERMAN NETHERLANDS	PRESENT
30				19,7
45	50	34	29	[illegible]
60				9.4
90	35	11	13	8,4
120				14,1
135	22	22	39	
150				28,5

???

These results are bizarre in relation with other authors results. But course we can remember that Indians are not so ~~strong~~ ~~(2/3 of~~ (½ to ⅔ of european and american workers??)

RAY G.G., SEN R.N., NAG P.K., DE A., BASU (1981)

Relationship between segmental and whole body weights and volumes of indians

J. HUMAN ERGOLOGY 10 35-48

Same research as SEN ~~and co~~, RAY, NAG (1976) with 3 cadavers more (2 males, 1 woman) that makes 8 (7 male 1 woman)

now ~~B~~ Trunk ~~57.~~ 56,8 of Body weight

limbs 30,6 " "

[The most ~~pleasant~~ silly of this story is the comment :] The faster movement of the body segments of indians as compared to those of the westerners might be due to the lower segmental weights of indians

[Are these almost national prejudices compatible with the scientific reputation of the authors]

Height 165

Weight 37

|| are they even "normal" indians who weight usually 50 to 55 kg !!

VERY BAD

See SEN RAY NAG 76

MAITRA S.R., CHATTERJEE S., DAS S. (1.968)

Study on ionic concentrations during minimal, submaximal and maximal exercise

INTERNATIONAL JOURNAL OF PHYSIOLOGY

22 1.2 1-3

Very theoretical and non convincing paper

Papiers SET
avec Ch.
Wisner

]

(Department chnology,

From persor Calcutta State Transport Corporat..., the authors felt the need for a preliminary study when their are enough scopes for improvement in the design of these buses from the view point of Ergonomics with special reference to safety, health, comfort and efficiency of the passengers, drivers and conductors.

A few simple modifications on the existing conditions during boarding the buses and standing and sitting arrangements inside the buses were suggested after taking into consideration the anthropometric and other linear measurements in different places inside the buses. Modifications were also suggested to improve the movability of the passengers and conductors inside the buses.

In order to assess the thermal conditions inside the buses with special reference to ventilation and air changes, the sling psychrometer and Kata thermometer readings were taken during the months of May and September, 1973. It was observed that the dry-bulb and the wet-bulb temperatures inside the buses were 5 to 7°F and 3 to 4°F higher respectively than those outside. It was seen from the readings of the Kata thermometer that the air movement inside the over-crowded buses was very poor (about 2 ft/minute), whereas the air velocity required is at least 250 feet per minute. The air space available for each passenger is about 10 to 20 cubic feet whereas the normal requirement is 500 cu. ft. The conditions inside the buses could significantly be improved if a double-monitor-roof with small air entry pockets on the roof as well as on the sides and drop-windows with more exposed areas as suggested, are provided.

Passengers' subjective assessments on noise and vibration were taken. The sources of noise and vibration in the buses were from unnecessary blowing of the horns of the same bus and other vehicles, noises from the bus engine, sudden

TEXTES

SEN

Ind. J. Physiol. & Allied Sci., 1973 Vol. 27, No. 4

ARE THE CALCUTTA PUBLIC BUSES ERGONOMICALLY DESIGNED ?

By
Rabindra Nath Sen and Pranab Kumar Nag

(Department of Physiology, University College of Science & Technology, Calcutta University, Calcutta-700009)

From personal experiences as passengers in the buses of Calcutta State Transport Corporation, the authors felt the need for a preliminary study when their are enough scopes for improvement in the design of these buses from the view point of Ergonomics with special reference to safety, health, comfort and efficiency of the passengers, drivers and conductors.

A few simple modifications on the existing conditions during boarding the buses and standing and sitting arrangements inside the buses were suggested after taking into consideration the anthropometric and other linear measurements in different places inside the buses. Modifications were also suggested to improve the movability of the passengers and conductors inside the buses.

In order to assess the thermal conditions inside the buses with special reference to ventilation and air changes, the sling psychrometer and Kata thermometer readings were taken during the months of May and September, 1973. It was observed that the dry-bulb and the wet-bulb temperatures inside the buses were 5 to 7°F and 3 to 4°F higher respectively than those outside. It was seen from the readings of the Kata thermometer that the air movement inside the over-crowded buses was very poor (about 2 ft/minute), whereas the air velocity required is at least 250 feet per minute. The air space available for each passenger is about 10 to 20 cubic feet whereas the normal requirement is 500 cu. ft. The conditions inside the buses could significantly be improved if a double-monitor-roof with small air entry pockets on the roof as well as on the sides and drop-windows with more exposed areas as suggested, are provided.

Passengers' subjective assessments on noise and vibration were taken. The sources of noise and vibration in the buses were from unnecessary blowing of the horns of the same bus and other vehicles, noises from the bus engine, sudden jerkings of the buses for not changing the gear when required, vibrations due to rough roads and loosely fitted parts of the body of the buses. These high frequency noises and low frequency vibrations are subjectively very much irritating, and fatiguing to the individuals.

The pollution problem from the exhaust of these Diesel buses could be tackled, if contrary to the existing condition, the exhaust pipe is extended to the roof of the buses where the exhaust and anti-knocking fuel gases will be diluted into the upper part of the air strata and thereby these polluting gases, fumes, smokes, etc. will not be directed to the nose level of the passers-by.

As proper ergonomic displays are important both to the drivers and passengers, it was suggested that the route numbers should be painted black on white background. The height and width of the bold numerals should be 8 inches (20 cm.) and 5 inches (13 cm.) respectively when the reading distance is about 150 feet (46 meter). The numerals should be placed in the middle of the front-destination-display-board as well as on the back and side of the bus, so that passengers will not have any confusion as to their destination. Colour of the buses should be selected from the population reactions and different categories of buses such as, 'Limited', ordinary, without seats etc. should have different colours, as suggested.

In designing the driver's cabin, the distance between the seat level and the bottom edge of the steering wheel should be sufficient (about 13 inches or 33 cm.) to permit the legs to move high enough to put the feet on the pedal. In order to avoid accidents, overall visibility of drivers specially on the right side of the buses should be increased. Gear changing rod should be modified as suggested. To avoid errors on the part of the driver, hydraulic aided automatic differential gear with accelerator could be provided. Modifications of the traffic signals as suggested should also be considered. The best combination for the road signal lights was found to be red, amber and green in order from the top.

In total about sixty different modifications for improvement were suggested for implementation in future designs.

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Annexure E.

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+ Further list 25 more papers

Research studies recently completed and reports & papers under Preparation.

1) Physiological studies on transport workers in docks.
(2) Studies on physiological responses of workers in glass factory.
(3) Studies on physical fitness of workers in Bombay.
(4) Studies on Physiological factors (Age, Temperature, Occupation, etc Limiting Work Output of Indian workers).
(5) Physiology cum productivity study in a radio manufacturing factory.
(6) Physiological studies on workload and thermal stress in a shoe manufacturing factory.
(7) Physiology cum productivity study for rationalization of work and rest cycles in the forge shop of an automobile factory, in rolling mill, in a foundry, in a glass factory and other hot industries.
(8) Measurements of the levels of noise in different sections of a Rayon factory and method for reducing the level.

Research ~~Containing~~ Continuing.

(1) Studies on circadian (Biological) rhythm with reference to shift work in factories.
(2) Studies on physiology of sitting posture and development of an Ergonomic stitting arrangement for Indians.
(3) Studies of occupational and performance work capacity of students and Athletes.
(4) Effects of heat stress on occupational work capacity of Indians.
(5) Electromyographic evaluation of light work tasks.
(6) Biochemical substances as stress indicators in blood and urine.
(7) Anthropometric measurements in designing of home, school and office furniture.
(8) Determination of body composition, nutritional status and maximal work capacity in local problems.
(9) Determination of the zone of comfort for local Indian population during different seasons.
(10) Evaluation of method for separation of male and female spermatozoa.

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Some anthropometry of people of eastern India

JOURNAL OF THE INDIAN ANTHROPOLOGICAL SOCIETY

~~192 year~~ 12 199-206

192 ~~persons~~ males from different sectors of unorganized(?) workers were ~~selected through~~ chosen randomly(?) from 18 localities of Eastern part of India. They were belonging mostly to lower socioeconomic status & their average monthly income was about 150-200 rupia (weavers 13 rs/a day that is for 25 working days 331,5 and for 30 days 397,8) see SEN and GHOSHTHAKUR (1984)

Sen measured the body dimensions of people of Eastern and Western part of India in order to assess the influence of environmental variations [!!] . The primary purpose of this publication is to have information about somatotypes [the answer is : low body weight 49,7 kg, low bone diameter they are mesoectomorphic HEATH-CARTER rating scale and not : they have nutrition problems nice generalism !!!]

53% agricultural workers

22% load handling workers

14% moderate and semiindustrial workers

11% light job workers

Age 15 - 40 y

In this [special] sample

percentile	5	25	50	75	95
weight	36	41	46	50	57
height	151	157	162	166	172

Body weight and chest circumference is approximately ~~10%~~ 5 to 10% higher among industrial workers

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DOUBTFUL

J. Indian anthrop. Soc., **12** : 199-206 (1977)

Some Anthropometry of People of Eastern India

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ABSTRACT : The statistical samples of some groups of unorganized agricultural and non-industrial workers from the eastern part of India, were selected in order to gather information about the body types and body dimensions, which are commonly used in Human Engineering research. From the low body weight (75 percentile value: 49.7 kg). low bone diameters (75th percentile value of right radio-ulnar and epicondylar breadths were 5.6 and 9.8 cm respectively), it may be inferred that the workers had predominantly meso-ectomorphic body componnents, based on Heath-Carter somatotypic rating scale. It is suggested that the reference body weights of East Indians are within 45 and 50 kg. From 29 measurements it was observed that the anthropometric dimensions of unorganized workers were very similar to those of other industrial workers. A series of regression equations were constructed between the different anthropometric variables. Though the sample was small, these equations might serve some purpose for predicting different anthropometric dimensions of at least East Indians, since these are quite frequently required by the Human Engineers.

Sen (1954, 1960, 1964) measured the body dimensions of people in Eastern and Western part of India in order to assess the influence of environmental variations on body size. Sengupta and Sen (1964) reported various body measurements of male textile mill workers for the purpose of designing the textile mill machineries. Saha (1968, 1969) measured body dimensions of female workers in relation to the sitting arrangements. Many studies on physical anthropology of Indian population have been reported in relation to genetics (Indian Statistical Institute, Calcutta, Summary report, 1963 to 1975).

The primary purpose of collecting anthropometric data of the Indian population reported in the present contribution is to have essential information about the body types (somatotypes) and body dimensions which are commonly employed in Human Engineering research. Though important in respect to the designing of tools and machineries for the unorganized

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agricultural and non-industrial workers, these types of anthropometric data for the Indian population is meager. In the present contribution 192 people from different sectors of unorganised workers were selected.

MATERIALS AND METHODS

The subjects were chosen randomly from 18 localities of Eastern part of India for the anthropometric study and mostly they were belonging to lower socio-economic status (average monthly income was about Rs. 150 to 200 only). Only 29 different anthropometric measurements were taken. The definitions of the anthropometric dimensions were followed as per the Conference on standardization of anthropometric techniques and terminology (Hertzberg 1968).

Portable platform balance with minimum readability of 0.05 kg. was used for the measurement of body weights ; Harpenden skinfold caliper (Edwars et al. 1955 ; manufactured by British Indicators Ltd) and USAMRNL skinfold caliper (Best, 1953 : manufactured by an Indian firm) which are supposed to exert a constant pressure of 10 gm per sq. mm at varying opening of the jaws were used for comparing the measurements of skinfolds.

The measuring rod, sliding caliper and steel tape were calibrated against standard mm scale. The weighing balance and the skinfold calipers were frequently calibrated against standard weights and necessary adjustments and precautions were taken when the instruments were used. During the measurements of body dimensions the instruments were handled in such a manner as to avoid excessive compression of the underlying tissues. Most of the measurements were taken in the afternoon. Although there is a gradual diminution of body height from the morning to the afternoon as noted by Keys et al. (1950) and Sen (1960), no attempt was made to see such variations, if any, for other measurements. The anthropometric measurements were expressed as the partition values.

The landmarks of the skinfold sites selected were as follows :

Biceps—Over the mid-region of the anterior aspect of the muscle with the arm hanging vertically :

Triceps—Over the mid-point between acromion and olecranon processes marked on the posterior aspects of the arm and the folds are measured with the arm hanging vertically ;

Chest—Over the skinfold between the shoulder and medial to the axilla, running diagonally at 3 to 4 cm above the nipple ;

Mid-axilla—Over the vertical fold of the mid-axillary line, approximately across the fourth and fifth ribs ;

Sub-scapula—Just over the tip of the scapula at an angle of about 45° to the vertical, medially upwards and laterally downwards ;

Supra-iliac—Over the crest of the ilium at the mid-axillary line ;

Abdomen—Over the horizontal fold at the right side of umbilicus, distance around 4 cms. ;

Thigh—Over the anterior aspect of the thigh at its maximum circumference ;

RESULTS AND DISCUSSION

It is stated earlier that the subjects were chosen randomly ; however, the persons involved in different occupations were taken as our subjects, without giving much attention to the wide range of ages, since this type of random sampling irrespective of age-groups will give a better stratagem (Ross and Wilson 1974) based on the concept of a theoretical reference man. The age of the selected workers varied between 15 to 40 years, with one or two exceptions. The groups consisted of 53 percent agricultural workers, 22 percent load handling workers, 14 percent moderate and semi-industrial workers and 11 percent light job workers.

The differences in the values obtained from the measurements of the skinfold of the same site by the two calipers mentioned above were highly significant statistically. The Best caliper recorded consistently higher values compared to the Harpenden. One of its possible reasons is the high frictional resistance of the movable parts of the Best caliper (Sen, Chakraborti and Nag 1975). The data presented in this paper is only with the Harpenden caliper.

The partition values (5th, 25th, 50th, 75th and 95th percentiles) of the anthropometric variables of the unorganised workers are given in Table 1. From the low body & bone weight (75th percentile values of right radio-ulnar, olecranon and epicondylar breadths were 5.6, 8.1 and 9.8 cm respectively), low body fat [the body density was determined using the formula of Durnin and Rahaman (1967) and the body fat (mean 9.89%) from Siri (1956)] and the co-efficient of variation (23.4%) and low ponderal index of all the groups of workers, it may be inferred that the workers were predominant of meso-ectomorphic body components, based on the Heath-Carter somatotypic rating scale. From the results of this study and other previous studies (Sen 1964 ; Sengupta and Sen 1964 ; Saha 1968 and 1969 : Nag *et al.* 1975), it may be suggested that the reference body weight of the workers of Eastern India should be within 45 and 50 kg, which is important for the expression of absolute metabolic cost of work of the individuals. As the body weight is low the basal meta-

TABLE 1

Partition values of the different anthropometric measurements of East Indians

Measurement	Percentiles 5th	25th	50th	75th	95th
Age (yrs.)	13.5	16.8	20.5	25.6	36.7
Body weight (kg.)	35.9	41.1	45.9	49.7	56.9
Ponderal Index	21.9	22.2	22.2	22.2	22.4
Measurement (cm)					
Body height	150.8	156.6	161.5	165.7	171.9
Sitting height	37.2	38.3	39.0	39.9	41.1
Acromial height	123.1	128.6	133.2	137.8	142.3
Gluteal furrow height	67.2	72.9	76.1	79.8	83.8
Bi-acromial breadth	25.8	28.2	29.7	31.3	33.7
Bi-deltoid breadth	30.8	37.2	38.5	39.8	42.0
Chest breadth (mid-tidal)	22.1	23.8	25.1	26.2	28.9
Bi-trochanteric breadth	25.3	26.8	27.8	28.9	30.5
Epicondylar breadth (Right)	8.3	9.0	9.3	9.8	10.0
Epicondylar breadth (Left)	8.1	8.9	9.3	9.6	10.1
Olecranon breadth (Right)	6.7	7.3	7.7	8.1	9.5
Olecranon breadth (Left)	6.6	7.2	7.6	7.9	8.4
Radio-ulnar breadth (Right)	4.6	5.0	5.3	5.6	6.4
Chest circumference (mid-tidal)	71.5	75.5	78.7	81.6	85.8
Biceps circumference	19.3	21.3	22.5	23.7	26.0
Upper thigh circumference	35.4	38.8	41.3	43.2	45.5
Lower thigh circumference	26.6	28.7	30.4	31.9	34.7
Skinfold (mm)					
Biceps (Right)	2.1	2.8	3.2	4.2	5.4
Triceps (Right)	3.5	4.3	5.2	6.3	10.0
Chest (Right)	3.6	4.1	4.8	5.7	7.2
Mid-axilla (Right)	2.8	3.8	4.6	5.2	6.9
Sub-scapula (Right)	4.6	5.8	6.9	8.4	11.9
Supra-iliac (Right)	3.0	3.9	4.7	6.1	11.2
Abdomen (Right)	4.2	5.1	6.3	8.0	12.5
Thigh (Right)	3.9	5.3	6.5	8.4	11.9

TABLE 2

Regression equations and the simple correlation co-efficients between the anthropometric variables

Dependent variable (Y)	Independent variable (X)	Regression co. eff. of (X)	Inter-cept	Standard error of estimate	Correlation co. eff. (r)
Age (yrs)	Body weight (kg)	0.18	18.18	0.39	0.112
Measurement (cm)					
Body height	,,	0.75	126.69	4.77	0.646
Acromial height	,,	0.63	104.90	5.46	0.530
Gluteal furrow height	,,	0.19	62.91	16.34	0.064
Bi-deltoid breadth	,,	0.24	27.67	2.62	0.436
Chest breadth	,,	0.19	16.80	1.67	0.517
Bi-iliac breadth	,,	0.08	21.02	1.62	0.277
Bi-trochanteric breadth	,,	0.10	23.51	1.66	0.326
Epicondylar breadth (Right)	,,	0.06	6.61	0.83	0.366
Radio-ulnar breadth (Right)	,,	0.03	4.08	0.58	0.267
Olecranon breadth (Right)	,,	0.04	5.56	0.69	0.326
Chest circumference (mid-tidal)	,,	0.54	54.48	3.48	0.641
Biceps circumference	,,	0.16	15.40	1.81	0.431
Upper thigh circumference	,,	0.41	22.77	3.62	0.545
Lower thigh circumference	,,	0.24	19.60	0.72	0.632
Triceps skinfold (mm)	,,	0.06	2.42	1.41	0.204
Sub-scapular skinfold (mm)	,,	0.05	5.08	2.11	0.114
Supra-iliac skinfold (mm)	,,	0.08	1.78	2.09	0.206
Body height (cm)	Acromial height (cm)	0.79	7.34	4.16	0.760
Gluteal furrow height (cm)	Body height (cm)	0.02	70.71	13.39	0.062

bolic rate is also low in case of Indians (Sen and Banerjee 1958a, b). It was observed that the anthropometric dimensions of these unorganised non-industrial workers were very similar to those of other industrial workers (Sen 1964 ; Sengupta and Sen 1964). The body weight, chest circumference, bi-trochanteric and bi-deltoid breadths were around 5 to 10 percent higher in case of industrial workers. However, when the values of the present study were compared with those of American and European studies (Damon and Stoudt 1963 ; Daniels 1952 ; McFarland *et al* 1953 ; McFarland

and Stoudt 1963 : Stoudt *et al.* 1960) it could be observed that the Indian values were much lower than the Westerners'. The ratio between the gluteal furrow height and the total length of the body was 0.455 in the present subjects. This ratio gives an idea about the relative length of the lower extremities. The higher ratio would indicate the relatively larger peripheral parts which might be an advantage for the Indians to increase the effective surface area for the maintenance of the body temperature in the tropics (Banerjee and Sen 1955 ; Sen 1960 : Nag 1976). The sleeve length might give us the idea about the relative length of the upper extremities.

As the human body is a complex structure of many interrelated segments, the physical dimensions of the body almost always require a knowledge of the nature of the interrelations between and among the segments. From the bisection of the segments of the Indian cadavers (Nag 1976 ; Sen, Ray and Nag 1976) it was found that each segment has a definite relationship with the whole body and other segments in regard to their weights and lengths. Based on these facts, the regression equations and the correlation co-efficients were obtained from the least square approximations (using IBM 1130 series Computer of the Calcutta University) between the different anthropometric variables which are given in Table 2. Although the total number of subjects in this study were small, these types of equations might serve as a basis for the prediction of different anthropometric variables of Eastern Indians till more data are obtained. Based on a larger number of observations, multiple regression equations will be much more useful for the prediction of a particular anthropometric variable, and these are very useful for the Human Engineers.

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CERTAIN ERGONOMIC PRINCIPLES IN THE DESIGN OF FACTORIES IN HOT CLIMATES

CERTAIN ERGONOMIC PRINCIPLES IN THE DESIGN OF FACTORIES IN HOT CLIMATES

from a paper by

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INTRODUCTION

The purpose of the present paper is to examine the application in hot climates of certain scientific and technological developments in connection with the design of industrial buildings where people work. The technological developments that have already changed the pattern of work, the leisure activity and the way of life of many people will undoubtedly affect many more in the coming decade, and it is essential to consider their influence on the human environment so that a total solution for the proper design of the working environment to achieve optimal efficiency, health, comfort, safety and production is attained.

In the Report[1*] of the Director-General, International Labour Office, Geneva, to the International Labour Conference in 1975, the importance of humanising working conditions and environment and the application of ergonomic principles to achieve these have been discussed. The necessity of taking proper measures in developing countries was also stressed, especially to avoid some of the ill-effects of industrialisation in advanced countries, to ensure that benefits for the many are not brought at the peril of the few.

It may appear that the requirements for an ideal environment for machines, such as the proper conditions of temperature, humidity, ventilation, cleanliness, lighting, etc., may be the same for the human operator. However, many workplaces which may serve the needs of the machines with great efficiency fail to provide the essential requirements of the human workers. A human being is immensely affected by the size, shape, pattern, colour or aesthetic qualities of his surroundings, while a machine is entirely unaffected.

It is not enough for buildings in which people work to be conceived as ideal enclosures for sophisticated plants, expensive equipment and complicated machinery. It is not sufficient for a factory or an office building to be just a shell designed around a production flow diagram. The production flow in a modern factory and the work pattern in an office may be of vital importance but the environment in which the workers carry out their tasks is even more important.

The amenities in the form of rest and recreational areas, canteens and other personal facilities are needed by the human operator but not by the machines. The average human worker requires a complete change of environment after a period of at least two hours for mental and physical relaxation and recovery, which are not necessary for the machines.

Human beings will always be required to control, operate and maintain the hardware of industry and commerce, and their safety, health, standard of living, comfort, welfare, efficiency and productivity all depend to a considerable extent on the environment in which they work.

Our society, which is rapidly being changed, must not only be technologically advanced for its survival - it must also be a truly human society. In order to achieve this goal, the builders of the working environment must take into consideration the way in which space, both within and around buildings, is created, and the shapes, sizes, patterns and colours of the space that affect the people and their ways of living - work and recreation.

Today, part of the industrial unrest which is affecting most of the industrialised countries of the world is due to the unbalanced advance of the technological progress with new machinery, new techniques and new materials being put into use often without any proper consideration or understanding of the human problems involved. Because of this, the development may well become self-defeating, for it is of little use devising means of vastly increasing production which may result in industrial strikes, non-cooperation of workers and misery for man and society. How a person lives and how he is affected by his surroundings at work and at home are of paramount importance; imposed life patterns are dangerous, affecting health and behaviour, and creating social unrest, labour turnover, etc. The problems of the working environment in hot climates are even more numerous and of higher magnitude than those in cold climates. Unless correct measures are taken at the very beginning of the design of the working environment, especially in hot climates in the developing countries, so that the creation of workplaces which are physically and mentally satisfying as well as efficient and economic is initiated, it may be too late to do much at later stages or it may be too costly to effect modifications, if at all possible.

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* For notes see end of paper.

Those who build factories and office buildings seldom used to consider the use of the principles of ergonomics (the science and technology of men at work)[2] with special reference to the effects that rooms, spaces and buildings have on people and their performance. A factory building may be suitable for today's needs but would almost certainly be inadequate for the needs of the future.[3]

In cold climates, workspaces with deep internal areas without windows and in a totally artificial and fully controlled internal environment in a building envelope designed as a solid block with multistoreyed structure due to site limitations or other factors are quite common, since these are more economical and can have more efficient use of available floorspace and the advantage of reclaiming wasted heat from lighting fittings, people, equipment, etc., for air conditioning. With a totally integrated artificially controlled environment, the window ceases to play an important part in providing either light or ventilation. Many of the factories in tropical countries are unfortunately merely copies of the design of the factories built earlier in cold climates and hence not appropriate to what is required for such an environment. Even the design of public buses in hot climates[4,5] are merely copies of those used in cold climates. As a result, the designs which were suitable for providing a warm climate inside the vehicle or factory environment in cold climates were most unsuitable for those in tropical climates, especially when there is a large amount of heat produced on some shop floors, such as in glass, steel and similar hot industries. Many of the new types of factory buildings, therefore, are worse than those found with traditional factory buildings in hot climates.

While standards of industrial building designs in cold climates in developed countries have been rising in urban situations and on isolated sites, most of the designs of industrial buildings in hot climates in developing countries in both urban and rural situations remained in the form of large corrugated iron or asbestos sheds linked only by open space or concrete yards, road or railway lines, waste lands and dumps of materials.

The architect should design the factory buildings in such a way as to bring out the best of the natural possibilities. The task of environmental control is to ensure the best possible indoor thermal conditions by relying on structural (passive) controls, which may obviate the need for any mechanical (active) controls; but even if mechanical controls have to be used, their task will thereby be reduced to a minimum.

APPLIED ERGONOMICS IN FACTORY DESIGN IN HOT CLIMATES

Four basic determining elements in every design problem are function, form, fabricating material and finance. An ergonomist must bring a harmony between these elements in the design of factories for hot climates.

Some of the theoretical aspects of the industrial design of the working environment and factory organisation from the viewpoints of architecture and ergonomics, including psychological aspects, have been discussed earlier.[6,7,8]

An ergonomic study[9] to help design the buildings of a drug factory and also an estate for pharmaceutical industries under the Government of West Bengal in India was undertaken by the Ergonomics Laboratory of Calcutta University, based on some of the principles of ergonomics discussed in the present paper.

The important factors in the proper design of the factories are:

(1) the site in relation to human habitation, landscape, vegetation, altitude, etc.; whether near the periphery of a town or in rural situations or in a valley, etc.; to protect from flood, earthquakes, storms, insects, termites, etc.; to avoid inversion temperature, pollution, etc.; to have good ventilation, low humidity, etc.;

(2) the orientation of the buildings, including roofs, walls, windows, etc., in relation to the wind direction, angle of solar radiation, etc.; to have the best natural ventilation and minimal thermal heating of the buildings, in relation to human comfort, activity and efficiency;

(3) the insulation and thermal capacities of the building materials;

(4) the use of sound material and the form of construction;

(5) correct design of workspace, windows, doors, stairs, corridors, etc., based on the static and dynamic body measurements and motion of the workers.

It is so obvious that the types of factory buildings and building materials for cold climates cannot solve the problems of factories in countries where heat is the dominant problem, where, due to economic reasons, the consequences of poor design cannot be compensated by very costly mechanical air conditioning, and where the workers differ in body form, thermal responses, etc.

Design in relation to meteorological conditions, site, location and layout of surroundings

It is very important for the location and design of factory buildings to consider the meteorological data over the years concerning rain, temperature, sunshine, humidity, speed and direction of wind and smog, etc. If the yearly data are not recorded and analysed, it is essential to have at least data for 12 months for selection of sites and design of factory buildings. Analyses of many of the elements of micro-climate have a deciding role on the site and location of factory buildings, particularly in tropical climates.

Normally, the climate is about 1.5°C cooler for every 300 m elevation in altitude and the factory buildings are more exposed to greater wind speeds, though there may be slightly more solar radiation due to less absorption.

Open, flat or convex sides of the land have the advantage of higher wind speed, but the solar radiation may be greater due to reflection on the surfaces. In contrast, concave forms, such as valleys and hollows, generally have greater mean day temperature, less wind speed and lower night temperature. There are also possible effects of temperature inversion in valleys (Fig. 1). In temperature inversion the normal temperature gradient from warm air near the ground to cold upper air is reversed and cold air is held below a layer of warmer air. This condition, usually invisible, occurs frequently and even in flat sites, as shown in Fig. 2. When this happens the polluted air cannot rise, and so will be trapped near the ground level. It is obvious that factory chimneys of inadequate height in an area of frequent temperature inversions can be a regular source of nuisance.

If an industry is allowed to be situated in the middle of the valleys to gradually spread out until all flat land is filled, it may cause clouds of dusts and smoke to hang over the valleys, as presented in Fig. 3.

The Katabatic flows of air and temperature inversions in valleys are to be considered. The flow of cold air down valley sides occurs in frequent flushes. Regional winds are deflected as a down-wash into a valley and these often carry smoke and fumes down to the floor of the valley.

Local features, including the different types of buildings can substantially modify the air movement and air temperature of the working environment. In olden days, heavy-weight stone or brick buildings with high thermal capacity and with high ceilings were being used in tropical climates to provide comfortable conditions during the summer months as well as in winter. Nowadays, because of the costs, very light-weight buildings with low thermal capacity and with thin concrete slabs are being used, which could heat up quickly during the day and cool down quickly during the night. When large glass windows are provided to increase the natural daylight, it facilitates entry of solar radiation also, which warms the surfaces inside the room, which in turn re-radiate, and this results in the uncomfortable conditions experienced inside the building.

It would be very useful for the designer to know the time of the day and the frequency of observations of sky conditions. A single average figure giving the sky conditions for a typical day of a given month may not reveal significant differences, e.g., between morning and afternoon conditions, which may affect the design of roofs, overhangs and shading devices.

It is important to know the frequency, likely duration and nature of some rare events such as dust storms, thunder storms, earthquakes, tornadoes, hurricanes, floods, etc., since the designer must classify these rare events into those which affect human comfort and those which may endanger the safety of the factory

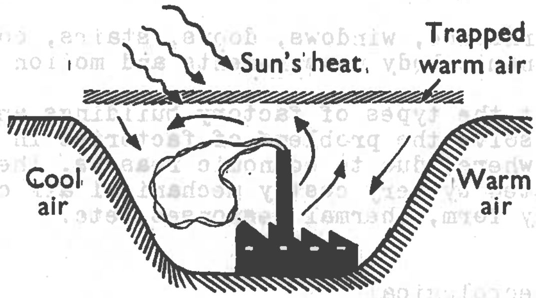


Fig. 1: Possible effects of temperature inversion for a factory in a valley.

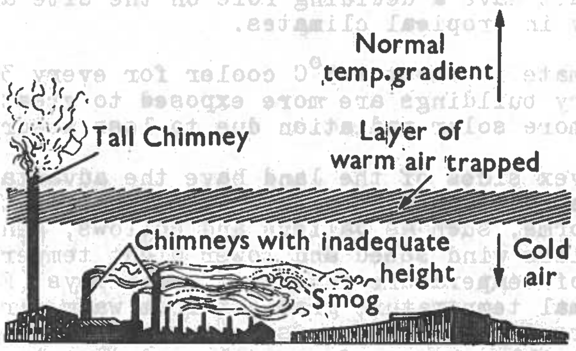


Fig. 2: The effects of a temperature inversion in trapping fine dusts, smoke and fumes near to ground level. Very tall chimneys or stacks only are able to penetrate the inversion layer and discharge their fumes in the rising air.

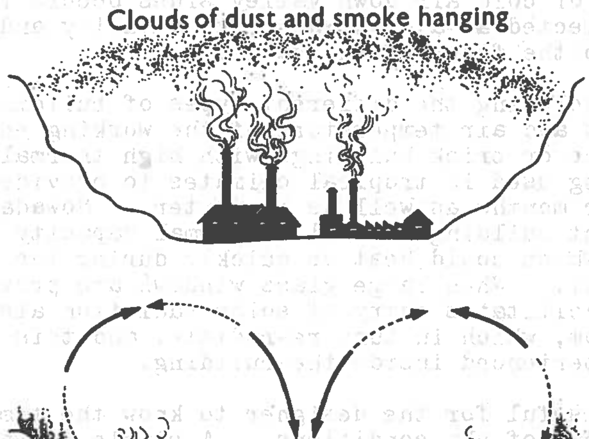


Fig. 3: When factories are built in the middle of valleys, it may cause clouds of dusts and smoke to hang over the valley.

buildings and the lives of the workers. Vegetation, though generally regarded as a function of climate, can influence the local or site climate of a factory. It is an important element in the design of outdoor spaces, providing sun-shading and protection from glare.

The nature and extent of climatic deviations and also their likely effects on the intended building should be assessed early in the design stage, before one is committed to a certain solution which may prove to be difficult to rectify.

There is always a reduction in wind speeds near to the ground - down to 40 per cent over rough terrain and 30 per cent in urban centres - but under certain conditions with less slopes, funnelling, sharp ridges and solid obstructions, wind speed may increase due to suction, turbulence and vortexes as shown in Fig. 4. It is possible to locate sites which would experience a considerable degree of natural wind. The wind velocity on urban sites is reduced to less than half of that in the adjoining open country, but the funnelling effect along a closely built-up street or through gaps between tall building blocks can be more than double the velocity, as presented in Fig. 5. At the leeward corners of obstructions, strong turbulences and eddies can also be set up.

Wind speed can be reduced by 50 per cent by a long horizontal barrier at a distance of ten times the height and by 25 per cent at a distance of about 20 times the height. Hedges, shrubs and trees act as screens to reduce wind speeds near the ground, while having sufficient permeability to prevent excessive turbulence (Fig. 4). Trees reduce dust movement, give a "green" outlook from windows and provide desirable shade from solar radiation. A tall hedge or thick belt of shrubs above eye-level isolates the pedestrian worker or passerby from the mass of industrial plant or buildings. The advantages and disadvantages of trees, hedges, shrubs, etc., should be carefully considered.

In choosing the location of the factory, consideration should be given to siting it not far from workers' residential places so that it does not require several hours of travel to get to work.

The higher the temperature of the air, the more water vapour it can hold. Due to the lowest layer of air being heated by the ground surface during the day, its relative humidity (RH) is rapidly decreased and, as a result, the rate of evaporation is increased when water is available to be evaporated as with an open surface of water or with rich vegetation or with higher air movement. The situation is reversed during the night. On a clear night, especially with still air, the RH increases as the lowest layer of air cools.

The air temperature in a city can be about 8°C higher than in the surrounding countryside and a difference of even 11°C has been observed.

The relative humidity in an urban area is reduced by 5 to 10 per cent due to the quick run-off of rainwater from paved areas, the absence of vegetation and the higher temperature.

Olgyay[10] was the first to propose a systematic procedure for adopting the design of a building to the human requirements and climatic conditions. The system has limited applicability, as the analysis of the physiological requirements is based on the outdoor climate and not on that expected within the factory building in question. It is known that the relation of indoor to outdoor conditions varies widely with different characteristics of the building construction and design. The method, though suitable for application in humid regions where ventilation is essential during the day and there is little difference between the indoor conditions and those out of doors, could lead to erroneous conclusions if applied in hot, dry areas, particularly in hot industries in the sub-tropics.

These include problems of overheating in the summer, of underheating or excessive cooling in winter, of wetness during rainy seasons, etc. Those temperatures below which heating is necessary are 18°C during the day and 15°C at sunrise, although higher temperatures would be desirable.

The intelligent application of the principles of ergonomics to the design of factory buildings in hot climates necessitates some understanding of the heat transfer processes of conduction, convection, radiation and evaporation, as each play an important part in the heat gains and losses in the factory buildings and the workers. Without this understanding, the efficacy of building design may be considerably reduced in the proper use of different materials and in the details of construction to suit the comfort and performance of workers.

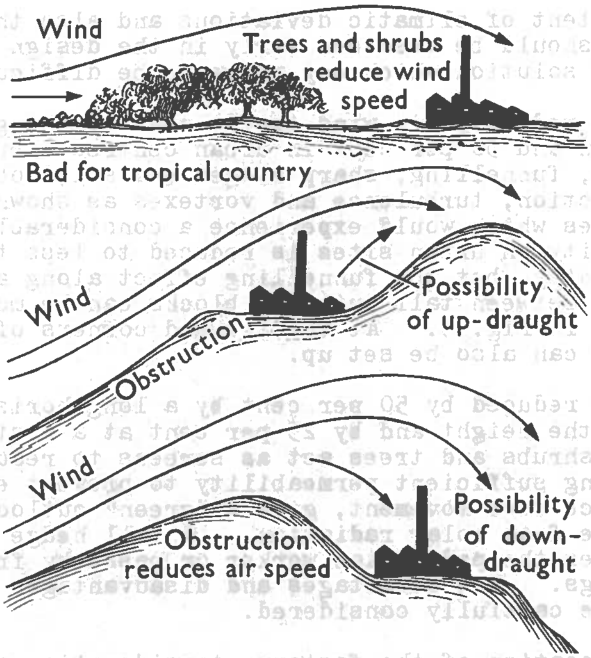


Fig. 4: Trees and shrubs reduce windspeed. Obstructions, though reducing air speed, may produce an up-draught or a down-draught due to funnelling, suction and other effects.

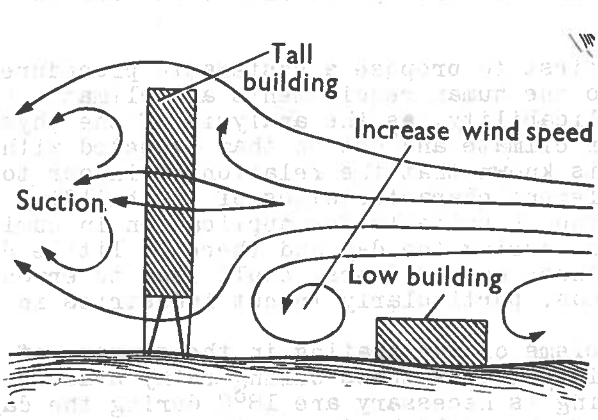


Fig. 5: Phenomenon of tall buildings producing increase of wind speed due to suction and turbulence near low building blocks.

Thermo-regulation, tolerance and comfort of workers

The thermal balance of the human body can be expressed by the following equation:

$$M - E \pm CD \pm CV \pm R = 0,$$

where M is the metabolic heat or energy expenditure, due to activity, shivering, etc., E is the heat loss due to evaporation of sweat or moisture, CD is the conduction heat from contact of warm or cold bodies, CV is the convection heat from the air hotter or cooler than the skin, and R is the radiation heat gain or loss from the sun and sky and hot or cold surfaces.

As soon as the sum of all the factors becomes greater than zero, the blood circulation to the skin surface is increased due to vasomotor adjustments, more heat is transported from the body core to the surface, and the temperature of the skin is elevated with a resultant acceleration of all forms of heat loss to the environment. Conversely, when the sum becomes less than zero, the blood circulation to the skin and hence the skin temperature are reduced and the heat loss processes are slowed down.

The normal skin temperature is between 31°C and 34°C. As the air temperature approaches the skin temperature, convective heat loss gradually decreases. Vasomotor regulation of the human body tries to increase the skin temperature to a higher limit (34°C), but when the air temperature reaches this point, there will be no more convective heat loss.

The four basic factors which directly affect human comfort are air temperature, humidity, air movement and radiation.

The summary of the thermal data at the actual places of work in different hot industries in India[11-16, 49] are presented in table 1. It will be seen that these workplaces are much hotter than similar places in cold countries.

Table 1: Mean maximum thermal data at some of the actual places of work in different hot industries in India

Industries	Dry-bulb temp. °F	Dry-bulb temp. °C	Wet-bulb temp. °F	Wet-bulb temp. °C	Relative humidity %	Globe temp. °F	Globe temp. °C	Air speed ft/min	Air speed cm/sec	CET (B) °F	CET (B) °C
Textile mills	99.0	37.3	97.5	36.4	92.0	99.5	37.5	375	190	92.5	33.6
Soap factory	97.4	36.4	81.6	27.6	88.0	100.0	37.8	420	210	84.6	29.2
Steel rolling mills	109.0	42.8	89.0	31.7	46.0	142.0	61.2	1 500	750	97.2	36.3
Coke oven battery	105.0	40.6	75.0	23.9	23.0	174.5	79.2	950	475	101.7	38.7
Foundry	97.0	36.1	83.0	28.4	55.0	135.5	57.5	400	200	95.3	35.2
Glass factory	152.0	66.7	93.0	33.9	10.0	210.0	98.9	1 500	750	105.0	40.6
Outdoors (in shade)	96.4	35.8	86.0	30.0	62.0	102.2	39.0	520	260	101.3	38.5

Note: CET (B) = Corrected effective temperature (basic).

High thermal load in hot industries in a tropical country increases the load on the cardiovascular system by increasing heart rate and blood pressure to force more blood to the skin for cooling by the evaporation of sweat. The high thermal load combined with metabolic heat increases the body temperature and at times may even cause heat disorders in hot climates, whereas the metabolic heat in workers of cold climates helps to combat cold.

For physiological comfort in hot, dry climates, buildings must be adapted to the summer conditions as, in general, the winter requirements will be satisfied by a building in which comfort in ensured for the summer. The low humidity in the hot, dry conditions allows an adequate sweat evaporation rate from the body even in still air, and thus air motion need not be great to prevent discomfort due to moist skin. Natural ventilation during the day is, therefore, unnecessary for evaporative cooling and undesirable for convective heat exchange, and the ambient air speed under "still" air conditions may be taken as 15 cm/sec. This slight air movement is the result of convective air currents caused by surface temperature discrepancies between differently oriented walls. Thus with a wind velocity of 16 km/h (10 mph), the indoor air speed would be expected to range from 35 cm/sec (70 ft/min) with poor ventilation to about 150 cm/sec (300 ft/min) with efficient cross-ventilation. Higher velocities are not necessary for comfort and may even be annoying.

Men at rest can tolerate a greater amount of thermal stress than do men doing hard work.[17] The more vigorous the work, the less easily do the workers tolerate severe thermal stress.

The energy expenditures at different industrial tasks performed by workers in hot climates[11-16,18-20,49] are found to be different from those of their counterparts in developed countries,[21,22] as shown in table 2.

The higher energy expenditure of similar industrial tasks in hotter climates is due to higher metabolism at higher tissue temperature, increased blood flow and sweat gland activity.[22] Moreover, due to mechanisation in developed countries, the peak workload of industrial workers has been reduced, whereas due to the problems of unemployment, poverty, etc., the workload of workers in developing countries did not change.

Table 2: Energy expenditure of Indian adult male workers in different industrial tasks

Industrial tasks	Mean Kcal/min	Range Kcal/min	Industrial tasks	Mean Kcal/min	Range Kcal/min
1. Cotton textile mills			4. Foundry		
Carrying bales	5.2	3.2-6.3	Furnace attending	2.1	1.8-2.4
Carrying laps	4.1	3.7-4.5	Moulding	3.9	3.0-4.8
Drawing	3.9	3.2-4.5	Core making, baking	4.0	1.9-8.5
Spinning (double side)	2.4	2.3-2.5	5. Glass factory		
Winding	2.8	2.7-2.9	Bottle making:		
Sizing	2.2	1.5-3.5	By hand:		
Weaving: 2 looms	1.8	1.3-2.3	Helping	2.6	1.6-3.3
4 looms	1.9	1.7-2.8	Cutting	2.3	1.9-2.6
2. Soap factory			Airing	1.6	1.3-1.9
Barrel or drum			By machine:		
opening	5.4	3.8-6.8	Stacking	1.3	1.2-1.6
Rosin breaking	6.1	5.5-6.7	Sorting	1.5	1.3-1.8
Pan unit attending	3.5	2.9-4.1	Attending furnace	2.4	1.8-3.3
Pumping	3.9	3.6-4.9	6. Manual material handling		
3. Steel rolling mills			Lifting	9.8	4.6-14.2
Billet pulling	3.8	2.6-4.5	Carrying	10.0	5.6-13.5
Billet conveying	4.1	3.6-4.7			
Front roughing	4.9	3.6-6.3	7. Laboratory work		
Bar holding	3.0	1.6-4.4	Standing working	1.7	1.2-2.1
Looping	2.9	2.8-3.1	Sitting working	1.3	1.0-1.6
Coiling, platform operating	1.4	1.1-1.7			

Maximal physical work capacity of industrial workers at comfortable temperature conditions in India[23,24] was found to be much lower (shown in table 3) than that of the westerners in cold climates. The thermal load in hot industries reduces the capacity further,[27,28] as given in table 4. Thus, the proper design of factories in hot climates plays a great role in reducing the thermal load, thereby increasing comfort, performance and productivity of the workers.

Table 3: Maximal physical work capacity (maximal oxygen uptake) of Indian adult male industrial workers with mean body weight (kg) 55.6 ± 0.93 and mean body height (cm) 165.0 ± 0.58 at comfortable thermal conditions

Groups	Maximal oxygen uptake Litres (STPD)/min	Maximal oxygen uptake ml (STPD)/min/kg
Age groups:		
20 - 29 yr (N = 37)	2.46 ± 0.05	45.23 ± 2.03
30 - 39 yr (N = 31)	2.33 ± 0.04	43.04 ± 1.75
40 - 59 yr (N = 16)	2.13 ± 0.03	34.96 ± 0.90
Occupation groups: (heaviness of jobs)		
Light (N = 7)	1.67 ± 0.02	30.94 ± 1.36
Moderately heavy (N = 19)	1.91 ± 0.05	36.22 ± 0.79
Heavy (N = 30)	2.27 ± 0.05	40.67 ± 1.41
Very heavy (N = 17)	2.50 ± 0.06	41.98 ± 1.99
Extremely heavy (N = 11)	3.17 ± 0.08	55.51 ± 2.26
All groups (N = 84)	2.31 ± 0.14	41.08 ± 1.56

Dry-bulb °F (°C)	Wet-bulb °F (°C)	Globe °F (°C)	Relative humidity %	Air speed ft/min (cm/sec)	CET (B) °F (°C)
83.0 ± 0.10 (28.4 ± 0.05)	67.8 ± 0.12 (19.9 ± 0.06)	83.0 ± 0.09 (28.4 ± 0.05)	47.1 ± 0.33	175.0 ± 2.37 (88.9 ± 1.20)	70.6 ± 0.06 (21.5 ± 0.03)

Mean ± standard error; N = number of subjects; CET = corrected effective temperature (basic).

Table 4: Maximal physical work capacity (maximal oxygen uptake) of Indian adult male industrial workers (N = 84) at three different thermal conditions

Heat stress index CET (B) °F	Heat stress index CET (B) °C	Maximal physical work capacity KgM/min	Maximal oxygen uptake Litres (STPD)/min	Maximal oxygen uptake ml (STPD)/min/kg
70.3 ± 0.34	21.3 ± 0.19	1 025.8 ± 27.2	2.31 ± 0.14	41.08 ± 1.56
80.7 ± 0.42	27.1 ± 0.23	935.8 ± 27.5	2.05 ± 0.05	36.43 ± 1.58
90.2 ± 0.25	32.4 ± 0.14	847.6 ± 27.2	1.81 ± 0.06	32.23 ± 1.36

N = number of subjects; Mean ± standard error; CET (B) = corrected effective temperature (basic).

Among the workers of the cold and hot climates accustomed to such climates, there are also differences in the thermal comfort levels[29,30,49] and the limits not to be exceeded without a risk of endangering health and efficiency considerably, as given in table 5. It is important to note that thermal balance is essential for thermal comfort but it can also be achieved by the thermo-regulatory mechanisms such as blood circulation, sweating, etc., of the body under conditions of discomfort.

Table 5: Optimum comfort zone with typical thermal conditions for Indian adult male industrial workers with usual clothing at different levels of activity in winter and summer seasons

Activity and seasons	Range of comfort		Typical thermal conditions								
	CET (B)		Dry-bulb temp.		Wet-bulb temp.		Relative humidity	Globe temp.		Air speed	
	°F	°C	°F	°C	°F	°C	%	°F	°C	ft/min	cm/sec
Very light work:											
Summer	78.8	26.0	90.5	32.5	74.0	23.4	47	99.0	37.3	500	250
Winter	73.0	22.8	73.5	23.1	56.5	13.6	32	94.0	34.5	30	15
Heavy work:											
Summer	68.9	20.5	82.5	28.1	65.0	18.3	38	90.0	32.2	700	350
Winter	64.5	18.1	75.0	23.9	55.0	12.8	25	80.0	26.7	100	50

CET (B) = corrected effective temperature (basic).

Body shape or the surface to volume ratio has an effect on the thermal preferences. A thin person generally found in hot climates has a much greater body surface than a short, fat person of the same body weight,[31-33] and he or she can dissipate more heat and will tolerate and prefer a higher temperature.

Dark skin of the people in hot climates containing the pigment melanin prevents the penetration of damaging ultraviolet rays and increases the heat emission from the body in the same proportion as it affects absorption; thus it is more resistant to the damaging effects of sunshine.

Men in the older age-groups tolerated severe thermal stress very nearly as men in the younger age groups.[34] In severe heat, the reaction of both groups was very nearly identical, whereas due to the higher body fat and greater amount of clothing, the females have some difference in thermal comfort and tolerance levels. Factories where only females would work should take this and other points into consideration in the design.

A reduction in the amount of work clothing will increase the ability of men to withstand thermal stress, except under conditions involving very great amounts of radiant heat or in circumstances where there is very fast-moving hot air. Men wearing the least clothing withstood more easily the higher temperatures.[35]

All this has a considerable bearing on the design of industrial buildings to produce optimal conditions for the workers. It is obvious that the same design of industrial buildings in cold climates would be very unsuitable for hot climatic conditions due to these differences.

For warm, wet conditions it has been estimated[36] that over 2,000 N/m^2 vapour pressure, every 1 m/s increase in air speed compensates for an increase of 300 N/m^2 in vapour pressure. When the air is completely saturated and warmer than the skin, air movement would only increase discomfort and heat gain. Fortunately, such conditions are seldom met in nature. The highest humidities, even in warm, humid conditions, are experienced when air temperature is below skin temperature, whilst the highest temperatures are accompanied by moderate humidities. But such conditions can quite easily be produced inside factory buildings of poor design and with bad management.

Materials and form of construction

Specific features of design and of structural materials[37] that affect the response of a factory building to exposure to climatic elements are the quantity of solar radiation absorbed in and penetrating the building, the air surface temperatures, the air velocity and the vapour pressure.

In a hot climate, the function of the building envelope is to moderate the daytime heating effects of the external air and solar radiation on the structure and its interior. At the same time, the rate of cooling during the night should not be over-reduced.

In choosing suitable building materials in hot climates, two ambient characteristics are of primary importance: the maximum temperature and the diurnal range dependent on vapour pressure level. A third significant factor is the absorbed solar radiation, which depends on the orientation and external colour of the building element in question. The most important thermo-physical properties are the thermal resistance and heat capacity, which may often be expressed together by the product of the two. But as the mechanisms of heat flow control operating through the two factors are different, the effectiveness, and hence the relative importance, of each with respect to physiological comfort within a building varies differently with the climatic characteristics.

The ground loses much heat by radiation, particularly on clear nights, and soon after sunset its temperature falls below that of the ambient air. The direction of heat flow is reversed from the air to the ground. The lowest layer of air becomes cooler.

A difference of temperature between the inside and the outside, or between different parts of a building, will result in a transfer of heat from the warmer to the cooler areas. Any wall, floor or roof will offer some resistance, but will not entirely prevent heat transfer. The purpose of thermal insulation is to restrict and delay the rate of transfer.

Insulation will be most effective under steady state conditions, or when at least the direction of the heat flow is constant for long periods of time, especially in heated or air conditioned buildings. Where the direction of heat flow is reversed twice in every 24-hour cycle, the significance of insulation will be diminished.

The effect of solar radiation on opaque surfaces can be combined with the effect of warm air by using the sol-air temperature concept of Mackey and Wright.[38] The magnitude of sol-air temperature influenced by the factors of absorbance and surface conductance shows that the selection of colour has some effect; the selection of material is, however, of greater significance. Variations in surface conductance are even less, but a lesser absorbance and a greater surface conductance would reduce the solar heating effect.

By far the greatest source of heat gain can be the solar radiation entering through the windows. This could, in fact, increase the indoor temperature far above the outdoor air temperature. Overheating is a problem in all tropical climates. For the reduction of solar heat gain through windows, four variables are within the control of the designer:

1. orientation and size of windows;

2. external shading devices;

3. internal blinds, curtains, etc.;

4. special glass.

Design of shading devices

In hot climates it is very important to shade the outside walls of a building exposed to high levels of sunlight.[39] This can be done by creating permanent screens or louvre blades, a reinforced canopy or externally applied venetian blinds, or planting tall trees with thick leaves or shrubs. These are very effective when they shade the east and west walls of the building, which are exposed to the morning and evening low-level sunlight.

Shade is required not only against direct solar radiation but also against diffused radiation from the sky which, in tropical regions, may reach very high intensities (0.75 Kcal/cm^2/day on a horizontal surface).

When horizontal adjustable louvres are used, they should be constructed so as to enable their opening at an angle of approximately 120°, so that when required they also direct the air flow towards the occupied zone. In multistoreyed buildings, window overhang shades tend to reflect an appreciable amount of solar radiation on the walls and into the windows of the upper storeys. The vertical shadow angle measures the performance of horizontal shading devices.

Vertical shading devices consist of lower blades or projecting fins in a vertical position. The horizontal shadow angle measures their performance. Narrow blades with close placing may give the same shadow angle as broad blades with wide spacing. It will be seen that this type of device is more effective when the sun is to one side of the elevation, such as an eastern or western elevation. The shading masks with segmental shape will be most effective when the sun is opposite to the building face considered and at a high angle, such as for north- and south-facing walls. To allow sun only at a low angle, this type of device would have to cover the window completely, permitting a view downwards only.

Egg-crate shading devices are combinations of horizontal and vertical elements. The many types of grille-blocks and decorative screens may fall into this category. The construction of shading masks for moderately complex shapes is effective for any orientation depending on detail dimensions.

Once the necessary shadow angles have been established, the design of the actual form of the device will be quite simple and it can be postponed to a later stage when it can be handled together with other considerations, structural or aesthetic, daylight or air movement.

The aridity in hot, dry areas is accompanied by several characteristics of importance to human comfort and to building design. Direct solar radiation is intense, up to 700-800 Kcal/m^{2}h on the horizontal surfaces, and may be further augmented by the radiation reflected from the barren, light-coloured terrain.

In hot, dry areas the main consideration is to reduce the impact of solar radiation on buildings and to provide shade in the streets, recreational areas, etc. All the internal roads leading to the different buildings of a factory should have shade from the trees planted on the sides of the pedestrian pavement. Where hot, dry winds are associated with dust storms, wind control should be aimed at protecting rather than obtaining the best ventilation. Internal courtyards and patios are often provided for social purposes and also as resting areas. During the day, ventilation is reduced to a minimum to exclude the hot, dust-laden outdoor air from the interior.

In warm, humid regions, the planning should be directed towards optimum ventilation conditions and maximum protection from solar radiation.

Design of roofs and walls

If a heavy-weight roof with an external layer of efficient insulating material, itself protected by a waterproof light coloured (whitewash) covering, is used, heat flow during the day from external to internal layers is restricted by the insulation and reflecting surface and only a small portion of the potential heat is absorbed in the elements.

High heat capacity concrete walls externally insulated by rockwool or expanded plastic and covered by waterproofing materials are suitable for this purpose. All external surfaces should be as near to white as possible. The high thermal capacity of the concrete layer reduces the effect on internal temperatures of any heat which thus penetrates.

The whole roof may be externally covered by a polythene sheeting at a distance of 10-20 cm above the roof surface. Polythene (polyethylene) is transparent to radiation of the wave length around ten microns emitted by the roof, placing little restriction on radiative cooling of the roof at night. The disadvantage of the method is the deterioration of the polythene sheets due to the exposure to the sun, so that they have to be replaced at intervals.

The alternative of double-roofing at much less cost, especially in factories in rural areas in hot climates, is to maintain vegetation on selected portions of the slanting roof.

Orientation and design of windows

In the equatorial location, the main windows should face north or south to avoid solar heat gain. At the higher latitude, though an orientation away from the Equator would receive the least sunshine, it may be desirable to have some solar heat gain in the winter when the sun is low, and so an orientation towards the Equator may be used where the workplace does not generate much heat. In both locations the minor openings at unimportant workplaces should be placed on the east and west sides. Solar heat gain in the west side can be particularly troublesome as its maximum intensity coincides with the hottest part of the day.

If wind is to be captured or a pleasant view is to be utilised, etc., the opening of windows may at times override the solar consideration.

It is generally believed that to give optimum conditions of ventilation, the inlet window should directly face the wind. Any deviation from this direction reduces the indoor air speed. However, this is not always so. In some cases, better conditions can be achieved when the wind is oblique to the inlet windows, particularly when good ventilation conditions are required in the whole area of a workplace. When the wind is oblique (at 45°) to the inlet opening of the same workplace, most of the air volume takes up turbulent, circular motions around the room, increasing the air flow along the side walls in the corners.

Very good ventilation conditions are possible in regions with westerly windows even when the long façade with the inlet windows is turned by 45° to the north-west or south-west, where shading is much easier.

The air movement could be grossly influenced by the way the window blinds or sashes open. If the hinges on the windows are fitted properly depending on direction of prevalence of the wind, the window blinds or sashes would act as deflectors to direct the wind through the windows, whereas if the hinges are fitted in the wrong way, the wind would be directed away from the room. In many of the factories in the tropical climates, just changing the hinges from one to the other side of the window frame may improve the climatic conditions greatly (Fig. 6). This point has been overlooked in many factories in hot climates.

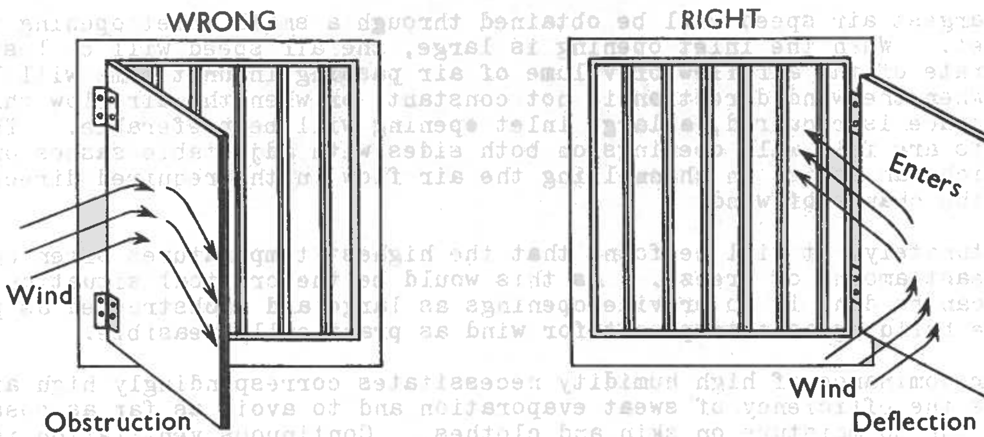


Fig. 6: Correct method of fixing window blinds or sashes so as to facilitate entry of wind from the prevailing direction of wind

Windows may be large but should be protected by movable insulated shutters; apart from small apertures for illumination, both windows and shutters must be closed during the day.

The most effective height of the windows from the human comfort aspect is about 0.5 to 1.5 m above the floor. It is preferable to use horizontally pivoted windows with upper hinges which, when open, would direct the air flow downwards. For hot areas, large sliding walls should be used, which may be kept open most of the time but closed during storms or rain to provide good control of the conflicting requirements for maximum ventilation alternating with wind, dust and rain protection during storms.

It is particularly important in hot areas to have two horizontal strips of window places in different walls, to provide the most adequate arrangements, one at the height of the floor and the other just below the ceiling, thus causing air motion in the room by thermal force during windless hours.

In a centrally heated factory room in a cold climate the opening of a small window for only five minutes may cost a fraction of a dollar due to loss of heat, whereas it may be rightly desirable to open all the windows for greater ventilation in a non-air-conditioned factory room in hot climates.

To minimise the blocking of air flow through fly screens, e.g., in a drug factory, it is preferable to install them at some distance from the wall, rather than directly on the windows, and extending them over a much larger area than the windows. When there is a balcony adjacent to the workroom, it is possible to ensure insect protection with less interference of ventilation by fixing a fly screen around the balcony, thus enabling the entry of air through a wider area.

Good ventilation not only keeps the workers cool and comfortable, it also helps dispersion of odour offensiveness, harmful dusts, fumes and smoke from the working environment which tend to increase with an elevation of air temperature.

In hot tropical climates, fans should be used to increase air movement to at least 0.5 m s^{-1}. High air speed increases the thermal comfort by increasing the evaporation of sweat and the heat loss by convection, both in hot humid and hot dry conditions.

The use of ceiling fans should be avoided in hot climates as these blow back the hot air from the top on to the workers. The inlet air blowers at the floor level or so-called "floor fans" or the circulators sucking the cold air from lower windows are much better. But at much higher air speed the body may gain heat from the hot air, which is to be avoided.

A loss of heat by evaporation of water is utilised in hot, dry climates by passing the air through meshes or weeds soaked with water. But in hot, humid climates this process cannot be used. Much of the sweat which is produced by the body is dripped away and not utilised for cooling the body by evaporation of sweat.

The largest air speed will be obtained through a small inlet opening with a large outlet. When the inlet opening is large, the air speed will be less, but the total rate of the air flow or volume of air passing in unit time will be higher. When the wind direction is not constant, or when the air flow through the whole space is required, a large inlet opening will be preferable. The best arrangements are full wall openings on both sides with adjustable sashes or closing devices which can assist in channelling the air flow in the required direction, following the change of wind.

Unfortunately, it will be found that the highest temperatures often coincide with the least amount of breeze. As this would be the critical situation, the best that can be done is to provide openings as large and unobstructed as possible to make the building as transparent for wind as practically feasible.

The predominance of high humidity necessitates correspondingly high air speed to increase the efficiency of sweat evaporation and to avoid as far as possible discomfort due to moisture on skin and clothes. Continuous ventilation is, therefore, the primary comfort requirement and affects all aspects of building design such as orientation, the size and location of windows, layout of the surroundings, etc. Even with the maximum ventilation there are limits under which comfort can be achieved in a warm, wet climate.

One of the chief causes of discomfort in warm, wet climates is the subjective feeling of skin wetness. Ventilation should ensure a sweat evaporation rate sufficient not only to maintain thermal equilibrium but also to enable evaporation of sweat as the sweat emerges from the pores, without accumulating on the skin. The provision of continuous and efficient ventilation, protection from the sun, rain and insects, prevention of the increase of internal temperature during the day and minimisation during the evening and night are the requirements for the design of a building in warm, wet climates.

To adequately cross-ventilate the areas of a factory building, either all the areas should be provided with doors, windows, etc., on both windward and leeward sides of the building, or those areas on the windward and leeward sides only should be given access through large openings to rooms on the opposite pressure sides.

To raise the building on pillars is advantageous in a warm, wet climate because it enables better ventilation by locating the windows above the zone of maximum damping of wind by the surrounding vegetation, etc., and also by enabling the cooling of the floor from below, which is particularly beneficial at night. In addition, the building is better protected from floods and from termites.

Occasionally, underground rooms are provided in which temperature fluctuations are further stabilised at a level close to the annual average; the summer temperatures are, therefore, much lower than in the buildings above the ground.

Conditions which are perfectly comfortable may produce adverse effects if constant and there is no change at all over prolonged periods.

One of the basic needs of the human being is change and variation, a fact which has been ignored by early research workers. This point is particularly noticeable in mechanically controlled environments, such as in air conditioned buildings, where the environmental conditions can be and often are kept constant within very fine limits. What the designer should aim at is a range of comfort conditions within which considerable variations are permitted.

It is quite interesting to observe that people enjoy natural, cool and fluctuating fresh breezes even when these stop for a few seconds at random, while people complain of the monotonous air movement at the same temperature and constant speed in an artificial climate. If these observations and causes are proved beyond doubt, in future the artificial climate may have to incorporate the random variation of air speed and air temperature within prescribed limits to provide the most comfortable conditions for workers.

The ordinary ventilation in the factories and workshops in hot climates should be at least 5.0 ft^3 (1.4 m^3) per person per minute. The air speed at the head level should be at least 100 cm/s (200 ft/min).

Design in relation to lighting, colour and noise

It is surprising that even today simple issues of heating, lighting and ventilation are too often inadequately considered and acoustic problems are not properly dealt with.

Where rooms or shop floors rely on natural daylight, the maximum practical depth is about 5 m (or 20 ft) from the window wall, and this may be increased to about 7.5 m (or 30 ft) where a scientifically designed combination of artificial and natural lighting is employed. Even mixed lighting by means of daylight and electricity limits the working depth of a shop floor.[40]

The effects of colour on people at work are to be considered for the scientific use of colours in the rooms and shop floors. In hot areas the "cool" blue or green colours, as against "warm" red should be used to give subjective sensations of coolness or impressions of reduced temperature.

The ceiling of a factory building plays an important role, particularly in reducing reverberant noise. Though people, furniture, wall linings, soft flooring, etc., all act to absorb noise to some extent, a considerable proportion of any noise travels upwards to the ceiling. There is a wide variety of acoustically absorbent materials suitable for use in ceilings.[41] The so-called "false" ceiling with sound-absorbing material not only reduces noise but also helps to insulate and thus minimises transfer of heat from a hot roof to the shop floor.

Design in relation to safety, health, pollution and welfare

Normally, factories should be so designed that the use of personal protective equipment against heat, dust, smoke, fumes, noise, accidental injuries, etc., is eliminated or at least minimal. If the hazards cannot be reduced at the source, then personal protective equipment has to be used, but one has to foresee that it might be impossible for the workers to endure wearing protective equipment in hot conditions.

The normal psycho-physiological conditions of activity and rest with recovery from stresses are impeded by unfavourable climatic conditions and the resulting stress on body and mind causes discomfort, loss of efficiency and may eventually lead to a breakdown of health or even cause accidents. It is a challenge for the designer of the factory building to strive towards the optimum of total comfort, i.e., complete physical and mental well-being.

A well-designed working environment includes not only suitable physical conditions of ample ventilation, heat dissipation, illumination and other comfort standards, but also the tangible and intangible amenities that can transform discontent and boredom into interest and a sense of participation by the workers, as for example the availability and use of shower facilities in hot climates, which are very much favoured.

Any industry that has a high "fatality rate" and a poor accident record is inefficient and it loses productivity through the loss of man-hours and discontinuity of work. Many unnecessary burdens are placed on the social services and the economy of the country as a whole and the degree of human suffering is immeasurable. A human life is irreplaceable. Loss of limbs and inability to work only bring misery and personal ruin.

For minimising accidents, the design criteria should take into consideration the major causes and frequency of different types of accidents from the records of similar industries in hot climates.

In hot, dry conditions, the chances of fire are much greater than in cold conditions, and hence greater precautions should be taken and better facilities provided for fire exits, structural fire barriers, safe internal and external access, especially in multistoreyed buildings. Industry has to count the cost of necessary precautions and control measures and the cost will in the long run have to be related to the total benefits to be expected from the process. The costs should be regarded as an essential part of the process and not simply as an added burden to be carried on the back of the manufacturer.

Factories and air pollution

The recent planning policy of most of the countries has been to encourage siting of industrial zones on the outskirts of new towns, or siting state or government-sponsored industrial estates outside townships, mainly to reduce the effects of pollution on the people living in the towns.[43,44] With the ever-increasing number of factories or industries, the threat of air, water and land pollution greatly increases.

To deal with aspects of pollution directly related to the design of landscape and buildings for industries, one has to consider the effects of waste materials or surplus energy generated by various forms of human activity in industry threatening damage to man's health, possessions, food supply, recreation and also to plants, animals and wildlife. In addition, there is pollution due to noise and other environmental nuisances generated from the factory buildings.

Air pollution arises from smoke, fumes and other gaseous emissions, dusts and grit from the factory processes directly discharged into the atmosphere. Obviously, the design of the factory building, including the ventilation system, chimneys, etc., must be done properly to cope with the minimum interference and pollution of the air by toxic and other substances. These pollution problems are enhanced by tropical climates. It is, therefore, very important that industrial plants and buildings be built to help in the effective control of pollution and its reduction.

The effect of a temperature inversion in trapping smoke and fumes near the ground is obvious. It is important to find out the height at which temperature inversion occurs. Very tall chimney stacks with correct height are able to penetrate the inversion layer to discharge their fumes in the rising air and thus avoid pollution (Fig. 2).

The heaviest air pollution comes from the burning of fossil fuels. Coal produces dusts and smoke which are considered specially harmful when trapped as fog. The photochemical smog which arises from the complicated chemical reactions of the emissions of the internal combustion engine in the presence of sunlight is an indirect effect of pollution from industry as it arises from transport movements. In order to avoid these, siting and design of the factory buildings, including the chimneys, should be made scientifically, and for this the effects of inversion and the effects of local microclimate conditions of mechanical and thermal turbulence upon the plumes from tall chimneys or stacks (Fig. 7) have to be considered.

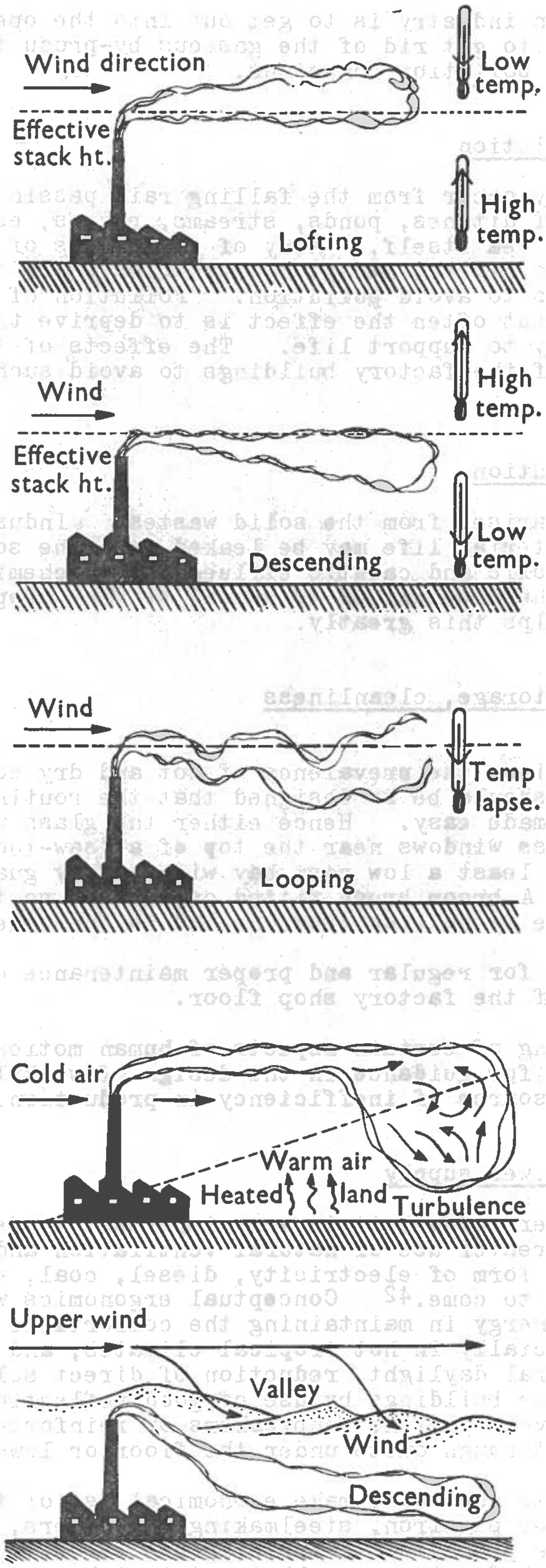


Fig. 7: The effects of local conditions of microclimate upon the trails of smoke from tall chimneys or stacks to show the importance of effective stack height

One trend of modern industry is to get out into the open and not worry about buildings. It is easy to get rid of the gaseous by-products, but the downwind public is becoming more pollution conscious.

Factories and water pollution

Water pollution may occur from the falling rain passing through smoky and polluted air, by ways of ditches, ponds, streams, rivers, estuaries, etc., to the direct polluting of the sea itself. Many of the wastes of the factory are directly discharged into rivers, except in countries where there is strict enforcement of control measures to avoid pollution. Pollution of water may not necessarily render it toxic but often the effect is to deprive the water of oxygen and thus reduce its capacity to support life. The effects of thermal pollution are similar. The design of the factory buildings to avoid such pollution is an important necessity.

Factories and land pollution

Polluting of land arises from the solid wastes. Industrial chemicals destructive to insects and bacterial life may be leaked into the soil from the waste dumped upon it. The toxic and caustic effluents from chemical plants usually involve great risk. The disposal of this must be done properly and the design of the factory building helps this greatly.

Design in relation to storage, cleanliness and maintenance

In tropical countries, the prevalence of hot and dry conditions leads to a lot of dust. The factory should be so designed that the routine storage and maintenance of cleanliness is made easy. Hence either the glass windows should be at the lower level, or the glass windows near the top of a "saw-tooth roof" factory, for example, should have at least a low cost bay with safety guardrails for safe, easy and regular cleaning. A broom brush fitted on rollers so that the windows can be cleaned from the outside by pulling from one end to the other is also useful.

Easy accessibility for regular and proper maintenance of machinery must be considered in the design of the factory shop floor.

Better understanding of certain aspects of human motion and body measurements for use of criteria and for guidance in the design of workplaces are necessary, as wasted movements are a source of inefficiency in production.

Design in relation to power supply

In the days of power crises, it is very important to design factories in hot climates to make much greater use of natural ventilation and daylight. The short supply of energy in the form of electricity, diesel, coal, etc., will be much more aggravated in the years to come.[42] Conceptual ergonomics would suggest the minimum use of these forms of energy in maintaining the comfortable conditions in the factory buildings, especially in hot tropical climates, and maximum use of natural cross-ventilation, natural daylight, reduction of direct solar radiation in heating the roof and walls of the buildings by use of good reflecting double-roofs or vegetation on the roof, good ventilation, sunbreakers or reinforced concrete canopies, forced cold air inlets through ducts under the floor or lower windows.

Nowadays it is quite common to make economical use of fuel by planning coke ovens, blast furnaces for pig iron, steelmaking converters, and fabricating mills on the same site, the whole plant thus comprising one large type of industrial installation making the best use of modern insulating materials and other means to prevent the escape of heat into the surroundings. In future, the factories in hot climates may advantageously utilise solar radiation on the roofs to cool the working environment of the workers.

Design of industrial estates

It is not enough to design one industrial building, even when it is well constructed. It is essential to have ergonomic considerations in designing industrial estates to reduce the cluster of small buildings and to improve the layout by various methods.[43] A logical and scientific flow diagram for intake of raw materials and for output of finished products should be worked out for all the factories in the group, so that efficient road, rail and conveyor systems can be made with common points for packaging, loading and unloading, and common facilities for maintenance, security, safety, medical clinics, canteen, recreation, sports and other organisations, and common services for electricity, fuel, gas, water, steam, compressed air, refrigeration medium, telephone, etc., and a ring circuit of refuse and waste disposal could be economically viable and useful. According to the suitability, any one of the different types of layout or plans[35] such as linear or radial or ring types (Fig. 8) may be used.

In good industrial planning, orderliness and over-all integration are combined and options for maximum future expansion are kept open.

Moderately compact internal planning of factory blocks will be of benefit for most of the year. Courtyard-type buildings are very suitable, since ventilation and light from both the external and internal sides are available. Buildings are to be grouped in such a way as to take advantage of prevailing breezes during the short period when air movement is necessary. A moderately dense, low rise development is suitable for these climates, which will ensure protection of outdoor spaces, mutual shading of external walls, shelter from the wind in the cold season, shelter from dust and reduction of surfaces exposed to solar radiation in the hot season. Wind speed above the level of the bulk of the industrial building blocks in the town, to which the higher buildings are exposed, is much higher. In a hot climate, in particular a humid one, this is obviously an advantage.

When the high buildings have also large horizontal dimensions, they divert the air flow above and over the blocks and cause "wind shadow" behind them (Fig. 4). On the other hand, when the horizontal dimensions are not much larger than those of the lower buildings, the turbulence and pressure difference created around them improves the ventilation conditions of lower buildings in their neighbourhood.

"Industrial parks" or recreation woodlands or "greens" are used as buffer zones between belts of industry.

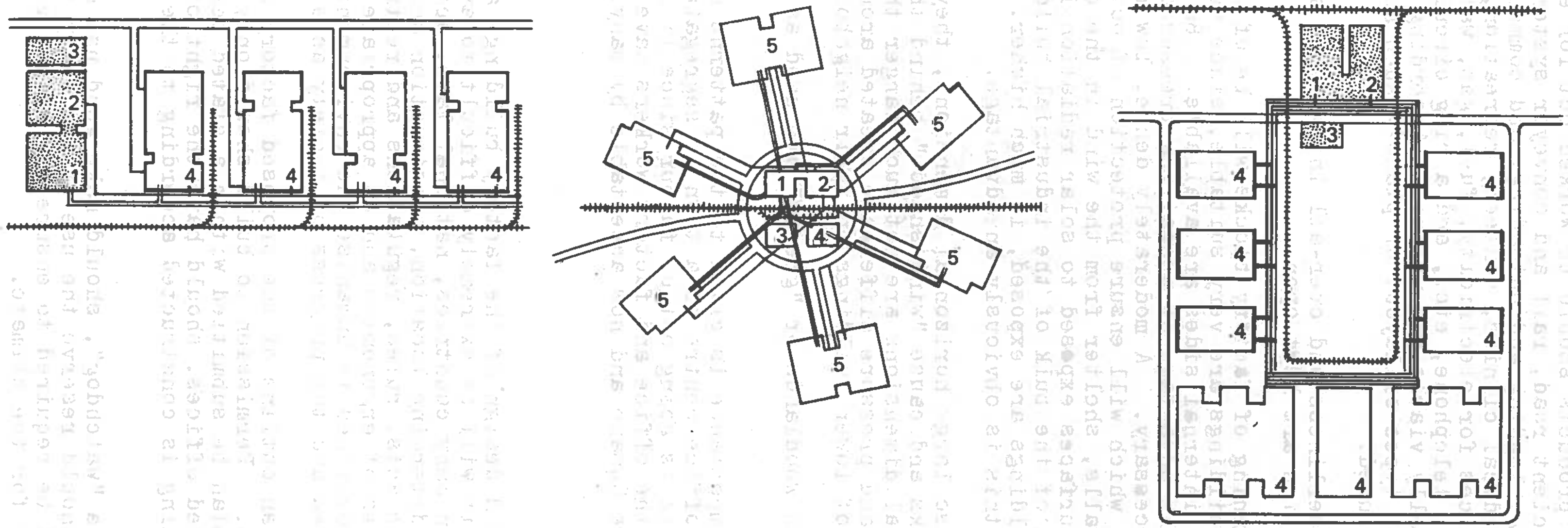
In some planning regulations, importance is given to the patterns of industrial development by which the commercial office centre of a town is segregated from residential and shopping areas. This is going out of favour since it has led to cities becoming dead at night after the office and factory workers have gone home. The type of mixed development is more humane and now acceptable by many.

Control on factory design

Unless the planning, location and design of the factory buildings are properly controlled from the very beginning, it will be extremely difficult to avoid grave situations in the years to come. In many countries, national laws, acts and local rules, regulations and restrictions determine location, construction and material usage in factory buildings.[44] These acts, rules, regulations and restrictions should also be based on the principles of ergonomics and on appropriate guidelines so that effective control can be established to humanise the environment and make for the proper development of the area and the progress of society as a whole.

An application to build giving an outline of the proposed factory should be made to the local planning authority. Permission to build should only be given with the condition that a detailed plan be submitted within a stated period. The local authority, through its appointed offices, should have the right of inspection of the work to ensure that the building is constructed according to the approved plan.

The factory inspectorate, like a "watchdog", should make good use of its loud bark and its nose for trouble, but should reserve the use of its sharp teeth for those rare occasions when they might be required to ensure the effective control of properly designed factories suitable for the climate.



LINEAR PLAN

1 Energy and Heat service
2 Refuse and Waste disposal
3 Welfare services
4 Factory space
═ Service links
═ Road access
╫ Rail access

RADIAL PLAN

1 Energy and Heat service
2 Refuse and Waste disposal
3 Rail goods storage and despatch
4 Welfare services
5 Factory space
═ Service links
═ Road access
╫ Rail access

RING PLAN

1 Energy and Heat service
2 Refuse and Waste disposal
3 Welfare services
4 Factory space
═ Service links
═ Road access
╫ Rail access.

Fig. 8: Different types of layout for factory buildings in industrial estates

Notes

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SEN R.N. , NAG P.K. (1978)

Residual carry over of acclimatization of sub-himalayan natives during graded work load at high altitude

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- very technical
- not useful for our work
- not commented

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No interest
Much better data are now available

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J. Human Ergol., 7: 55–63, 1978

RESIDUAL CARRY-OVER OF ACCLIMATIZATION OF SUB-HIMALAYAN NATIVES DURING GRADED WORK LOAD AT HIGH ALTITUDE

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During graded work load the nature of cardio-respiratory responses of seven sub-Himalayan Sherpa subjects (exposed group, EG), at 3,660 m altitude, were compared with those of a similar group of four subjects (control group, CG) at 2,000 m. The average rates of work calculated from the gross weight carried multiplied by the speed of walk ranged from 3,320 to 8,440 kg-m/min. Differences noted in the physiological responses between the exposed and control groups were due to hypoxia and cold at high altitude. At 3,360 kg-m/min, transient rise of pulmonary ventilation in EG over the values of CG was around 117 percent, whereas at 8,440 kg-m/min, the rise was only 40 percent. This hyperventilatory responses were always associated with the lowering of pulse rate. In the present study, highest average work pulse rate record at 8,440 kg-m/min of the EG was only 137.6 beats and at 3,360 kg-m/min the value was only 106 beats. The additional high energy demand for work at high altitude might be partly due to cold and higher work of breathing, and partly due to the difference in work load. The ventilation equivalent (BTPS), 39.44 *l* (at 3,360 kg-m/min) gradually decreased to 23.72 *l* at 8,440 kg-m/min in EG, and in case of CG these were varied only between 26.28 to 20.30 *l*. The oxygen pulse was markedly higher in EG, indicating a compensating mechanism for increased amount of oxygen intake.

Regarding varieties of difficulties encountered in man at high altitude and the possible adaptive mechanisms which help in the cardiovascular and respiratory adjustment to cold and hypoxia, several studies have been reported (MITCHELL, 1970; PUGH, 1965). The natives of high altitudes show blunted or decreased ventilatory responses (BALKE, 1964; LAHIRI *et al.*, 1972; SEVERINGHAUS *et al.*, 1966)

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and increased energy expenditure (NISHITH *et al.*, 1964; NAG *et al.*, 1976) at rest and during work, and in responses to voluntarily imposed hypoxic stimuli (CHIODI, 1963). It has been assumed that decreased ventilatory responses, which are secondary to decreased peripheral chemoreceptor sensitivity of the natives are developed during the first few months of life after birth (LAHIRI *et al.*, 1976) and by process of generations this hyposensitivity to hypoxia is being formed as a genetic characteristics of the natives. As an extension, the present study was carried out on eleven Sherpa subjects, born at 4,500 m and bred at moderate altitude (2,000 to 2,500 m) in the sub-Himalayan region to investigate further the nature of cardio-respiratory responses of Sherpas in graded work load during acute exposure to high altitude and to clarify whether there was any residual carry-over of acclimatization to the cardio-respiratory responses to those born at high altitudes (LAHIRI and EDELMAN, 1969; MITCHELL, 1970; SORENSEN and SEVERINGHAUS, 1968) even though they settled permanently and stayed a long period, more than 7 to 10 years, at lower altitudes.

METHODS

The study was conducted during the winter months of December and January. The subjects selected for study were healthy, young male Sherpas. A thorough enquiry was made to confirm the origin and tribe of the subjects, since there were admixtures of different tribes in the locality from where the subjects were selected. The physical characteristics, *e.g.*, age, body weight, body height, and a few skinfold thicknesses for the prediction of lean body weight and body fat were measured. It appeared that all were in good health and similar body status.

They were divided into two groups, consisting seven and four subjects. The field study on seven subjects was conducted at Sandakpu area (Dist. Darjeeling, India) at 3,660 m (barometric pressure: 480 mm Hg) altitude. The subjects from Darjeeling town (barometric pressure: 590 mm Hg) ascended to that altitude and were allowed to induce to that altitude for a complete week, since one week stay at the altitude is required for preliminary acclimatization to hypoxia and cold (WEIHE, 1966). After that the subjects carried graded loads (0, 25, 35, 45 and 55 kg) to a slight soft-snow covered fixed distance of 1 km on a mountain slope of approximately 12 to 15 percent uniform elevation at 3,660 m altitude. The average rates of work of the seven subjects calculated from the gross weight (body weight plus actual load carried in kg) multiplied by the speed of walk (m/min) at particular sin angle of the mountain slope were 3,360, 5,670, 6,230, 7,440 and 8,440 kg-m/min.

The other group of four subjects, which can be treated as control, stayed at Darjeeling town and carried different loads at 3,320, 5,470, 6,070, 7,140 and 8,330 kg-m/min on a treadmill at the horizontal level. Attention was given to impose equal work loads for both the groups, but for practical difficulties, it was not accurately possible.

Both at Sandakpu and Darjeeling, the subjects carried loads on the back by supporting the load by a circular strap around the forehead and by slightly inclining the body forward; and this is the usual mode of carrying loads at high altitude in the sub-Himalayan region. The environmental conditions, such as dry-bulb and wet-bulb temperature and air movement were recorded with the help of sling psychrometer and kata thermometer respectively. Throughout the experimental period the subjects wore woolen dresses and marching boots or hunter boots for their protection against cold. It was not possible to measure the insulative value of the clothings, but the average weight of the clothes were 2.5 to 3.0 kg only.

During 9 to 12 min of load carrying the average pulse rates of all subjects of two groups were counted every minute. The pulmonary ventilation was recorded with the help of KM-respirometer and the oxygen and carbon dioxide concentrations of the expired air were estimated by Scholander's method. The pulmonary ventilation and oxygen consumption were expressed at BTPS and STPD respectively: it is mentioned earlier that standard ambient pressure were 480 and 590 mm Hg for the above-mentioned places. No attempt has been made to reduce the gas volume to same standard sea level 760 mm Hg pressure. The ventilation equivalent (*l*, BTPS), a measure of respiratory efficiency, was expressed as the ratio between pulmonary ventilation (*l*, BTPS) and oxygen consumption (*l*, STPD); while the oxygen pulse, which is considered as a measure of one's oxygen transporting capacity, was expressed as the oxygen consumption (cc) per heart beat per kg body weight.

Some of these measurements were also undertaken at rest and during recovery from work. $\dot{V}_{O_2}$ max were determined by treadmill exercise in lower altitude subjects; while higher altitude group performed step-up test, as described in CONSOLAZIO *et al.* (1963).

RESULTS

The physical characteristics of the two groups of subjects are given in Table 1. It was observed that the two groups were belonging to same tribe and origin, and similar age and health. The dry-bulb and wet-bulb temperatures were 8.33 and

Table 1. Physical characteristics of two groups of subjects.

Variables	Control group (N=4)	Exposed group (N=7)
Age (year)	31.3±1.4	26.1±0.9
Body height (cm)	161.9±4.4	159.1±1.2
Body weight (kg)	53.0±1.3	54.2±1.3
Lean body weight (kg)	48.9±1.6	51.1±1.1
$\dot{V}_{O_2}$ max (*l*/min/50 kg body weight)	4.11±0.38	3.33±0.12

Values are means±standard errors.

6.39° in the lower altitude, and 0.40 and 0.17° in the higher altitude respectively. In the work place of lower and higher altitude, the air movement were 0.14 and 0.40 m per second respectively.

The rates of work of the Sandakpu (exposed group) and Darjeeling (control group) subjects and their corresponding cardiorespiratory responses are given in Table 2. The decrement of pulse rates and the increment of pulmonary ventilation of the exposed group in respect to the control group are shown in Fig. 1, in terms of the percentage decrement and increment. The rates of work of the two groups ranged from 3,320 to 8,440 kg-m/min. It is mentioned earlier that it was not possible to give exactly equal work loads for the two groups. The rates of work were slightly less in the control group.

Table 2. Cardio-respiratory responses of the two groups of subjects.

Variables		Control group	Exposed group
Rate of work: (kg-m/min)		3,320	3,360±24
	Pulmonary ventilation (*l*/min/50 kg, BTPS)	27.72 ± 1.89	59.29 ± 4.37
	Pulse rate increase over rest (beats/min)	35.6 ± 8.6	33.6 ± 4.1
	Oxygen consumption (*l*/min/50 kg, STPD)	1.08 ± 0.11	1.55 ± 0.17
	Ventilation equivalent (*l*, BTPS)	26.28 ± 3.28	39.44 ± 4.51
	Oxygen pulse (cc/pulse/kg)	0.189± 0.019	0.296± 0.032
Rate of work: (kg-m/min)		5,473±18	5,675±37
	Pulmonary ventilation (*l*/min/50 kg, BTPS)	44.71 ± 4.17	60.21 ± 2.18
	Pulse rate increase over rest (beats/min)	57.6 ± 0.3	46.8 ± 2.4
	Oxygen consumption (*l*/min/50 kg, STPD)	2.05 ± 0.25	2.02 ± 0.14
	Ventilation equivalent (*l*, BTPS)	20.30 ± 1.64	30.57 ± 2.28
	Oxygen pulse (cc/pulse/kg)	0.286± 0.025	0.319± 0.020
Rate of work: (kg-m/min)		6,068±67	6,231±65
	Pulmonary ventilation (*l*/min/50 kg, BTPS)	45.06 ± 2.80	61.74 ± 5.24
	Pulse rate increase over rest (beats/min)	61.7 ± 3.6	50.5 ± 2.7
	Oxygen consumption (*l*/min/50 kg, STPD)	2.17 ± 0.15	2.25 ± 0.15
	Ventilation equivalent (*l*, BTPS)	21.11 ± 2.4	28.23 ± 3.16
	Oxygen pulse (cc/pulse/kg)	0.306± 0.017	0.351± 0.023

Continued from Table 2.

Variables		Control group	Exposed group
Rate of work: (kg-m/min)		7,142±67	7,445±105
	Pulmonary ventilation (*l*/min/50 kg, BTPS)	51.23 ± 4.20	57.31 ± 2 83
	Pulse rate increase over rest (beats/min)	66.8 ± 4.3	53.7 ± 3.3
	Oxygen consumption (*l*/min/50 kg, STPD)	2.52 ± 0.29	2.58 ± 0.13
	Ventilation equivalent (*l*, BTPS)	20.30 ± 1.75	22.70 ± 1.52
	Oxygen pulse (cc/pulse/kg)	0.353± 0.050	0.390± 0.036
Rate of work: (kg-m/min)		8,332±78	8,440±150
	Pulmonary ventilation (*l*/min/50 kg, BTPS)	52.68 ± 5.19	73.05 ± 5.11
	Pulse rate increase over rest (beats/min)	71.7 ± 3.8	50.2 ± 4.4
	Oxygen consumption (*l*/min/50 kg, STPD)	2.48 ± 0.31	2.98 ± 0.17
	Ventilation equivalent (*l*, BTPS)	21.81 ± 2.88	23.72 ± 1.70
	Oxygen pulse (cc/pulse/kg)	0.324± 0.039	0.470± 0.024

Values are means±standard errors.

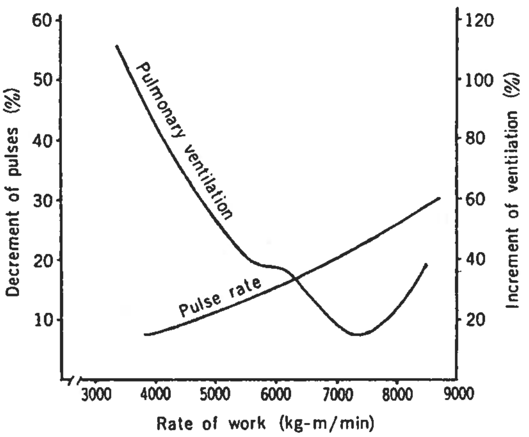

Fig. 1. The decrement of the pulse rates and the increment of the pulmonary ventilation of the exposed group in respect to the control group.

The pulmonary ventilation was markedly higher in the exposed group as compared with the controls. At the lowest rate of work (*i.e.*, average of the two groups was 3,340 kg-m/min), the transient rise of pulmonary ventilation of the exposed group was around 117 percent, whereas at the highest work load (*i.e.*, average of the two groups was 8,385 kg-m/min), the rise was only 40% over the values of the control group. The increase of work pulse rates over rest, as shown in Table 2, were much less in the high altitude, *i.e.*, about 10 to 20 beats/min. It has also been depicted in Fig. 1 that the decrement of the pulse rates of the exposed group, comparing controls, was only 6 percent at the lowest work load, whereas at the highest work intensities these were as high as 30 percent.

The oxygen consumption values per min per 50 kg body weight was fairly high in the exposed group. At 8,440 kg-m/min the oxygen consumption for the exposed group was 2.98 *l*/min/50 kg and the corresponding values for the control groups was only 2.48 *l*/min/50 kg at 8,330 kg-m/min, *i.e.*, 20% higher in the exposed group. These respective values were 92 and 60 percent of their maximum oxygen uptake. However, the oxygen consumption increased as linear functions with the rates of work as independent variable, only with difference in slope of the lines ($Y=0.0004X+0.356$, ± 0.630, for control group and $Y=0.0003X+0.402$, ± 0.408, for the exposed group). The corresponding simple correlation coefficients of the two lines were 0.7443 and 0.7545 (*i.e.*, below 0.1 percent level of significance).

There were wide difference in the ventilation equivalent with graded work in the high altitude. The ventilation equivalent at BTPS, 39.44 ± 4.51 *l* (3,360 kg-m/min) gradually decreased to 23.72 ± 1.70 *l* (8,440 kg-m/min) in the exposed group, whereas in case of control group it varied only between 26.28 ± 3.28 to 20.30 ± 1.64 *l* for similar work loads. As it was expected, the ventilation equivalent was negatively correlated with the rate of work ($r=0.4135$ and 0.5423 for control and exposed group respectively). The oxygen pulse was markedly higher, 0.296 cc/pulse/kg (3,360 kg-m/min) to 0.470 cc/pulse/kg (8,440 kg-m/min), in the exposed group than it was in the controls (0.189 cc/pulse/kg for 3,320 kg-m/min and 0.324 cc/pulse/kg for 8,330 kg-m/min), indicating relatively more amount of oxygen extraction at higher work loads.

DISCUSSION

In order to see the nature of cardio-respiratory responses in graded physical work and the residual carry-over of acclimatization of Sherpas, born at high altitude but bred at lower altitude, the present study was undertaken. Two groups of similar origin by birth and spent similar period of early life at high altitude were selected in the study. Approximately at 12 to 15 years of age they came down to the lower altitude and occasionally in once in two years they go up as high altitude porters, along with different expedition teams.

The rates of work of two groups were almost same, as revealed in Table 2. Differences in the physiological responses of the exposed group with the average responses of the control group were possibly due to the effects of physical factors, such as hypoxia and cold at high altitude. Since previous studies have been dealt with either moderate work loads (Lahiri *et al.*, 1972) or graded work loads given only in the simulated altitude (SATO and SAKATE, 1974; STERNBERG *et al.*, 1966), the higher work loads were given to the present subjects with an only purpose to actualise usual stresses imposed on the mountain dwellers in their day-to-day life.

The pulmonary ventilations were higher in the exposed group, as mentioned earlier; but it was interestingly noted that pattern of hyperresponses of the Sherpa subjects were less pronounced with gradual increase of rate of work at high altitude, than those of controls at lower altitude. But during prolonged exposure to hypoxia, the increase of pulmonary ventilation was reported to be more pronounced with the increase of rate of work among sedentary subjects (ASTRAND and RODHAL, 1970). The present findings of relatively lower ventilation were well corroborated with SATO and SAKATE (1974); their graded work loads, however, were given in simulated high altitude condition. It is true that the less prevalent effect of exposed group at higher work loads of the present study does not indicate that Sherpa subjects reached nearer to the maximum breathing capacity, since the highest ventilation record was only 73.05 ± 5.11 *l*/min/50 kg body weight (BTPS). The possible reason for higher ventilation at lower rate of work is not clear. Does it necessarily mean that an optimal level of stimuli is required for the chemoreceptors to get maximal response and further which there will be no marked change? Though it was understood that the decreased peripheral chemoreceptors sensitivity (LAHIRI *et al.*, 1972; MILLEDGE and LAHIRI, 1967; SEVERINGHUS *et al.*, 1966) was definitely persistent with Sherpa subjects, which they possibly developed during their first few months of life at high altitude (LAHIRI *et al.*, 1976; MITCHELL, 1970). However, it's quantitative measure is yet to be found out with special reference to duration of stay after birth at high altitude. In contrary, recently LAHIRI *et al.* (1976) reported that the normal hypoxic drive, although it matures only after birth in the high altitude, is thought to be substantially lost during adult life.

Along with different possible causes, as explained above, the differences in pulmonary responses of the present study may be partly due to the differences in work loads of two groups (NAG, 1976; NAG *et al.*, 1976). Notwithstanding, the hyperventilatory responses were always associated with the lowering of pulse rates (KELLOG, 1964) at high altitude. Hypoxia is attributed to the reflexes of the carotid bodies. Since one of its changes is vasoconstriction, the arterial blood pressure rises as a result of increased peripheral resistance and hence the reflexes of the baroreceptors of the carotid sinus and aortic arch would respond as bradycardia (BEST and TAYLOR, 1967). In the present study, the highest average work pulse rate record was only 137.6 beats per minute and at the lowest work load (3,360 kg-m/min) it was only 106 beats per minute. KELLOG (1964) and PUGH (1964) reported that the reduction of maximum pulse rate after several months stay at high altitude was as great as 40 to 50 beats per minute. The development of lowered pulse rate might be possible only after long term acclimatization, or possibly a genetic carry-over. While the sojourning lowlanders always show high pulse rates (ASTRAND and RODHAL, 1970). Thus, the present findings possibly demonstrate an important observation regarding the beneficial effects of relatively lower pulmonary ventilation and lowered pulse rate in better adaptability of natives at high altitude, although they came down to lower altitude during their early life.

It is clearly stated that oxygen consumption was fairly high in the exposed group. The additional high energy demand for work at high altitude might be due to the effect of cold (DB 0.389 and WB 0.167°) and also partly due to differences in work loads. The hypereactivity of the respiratory muscles required for the lungs to hyperventilate (LUFT, 1964) might also partly responsible for high energy demand at high altitude. As mentioned in Table 1, the maximum oxygen uptake of the exposed group (3.333 ± 0.115 *l*/min/50 kg body weight) at high altitude was 19 percent lower than the control group (4.110 ± 0.380 *l*/min/50 kg body weight), observed at lower altitude. The reduction of $\dot{V}_{O_2}$ max was reflected as overexertion (BUSKIRK and TAYLOR, 1957) of the subjects on the graded work loads, since each load demands higher percentage of $\dot{V}_{O_2}$ max, as compared with lower altitude subjects. PUGH (1964) carefully remarked that the reduction of the $\dot{V}_{O_2}$ max has a definite relationship with the increase of altitude.

There was marked decrease of ventilation equivalent in case of the exposed group and no such decrease was observed for control subjects. This fall of ventilation equivalent indicates relatively lower ventilation rate at higher rates of work to avoid further strain of the respiratory muscles; thereby it might cause higher amount of oxygen extraction in exposed subjects. It was noted that the average oxygen pulse (0.365 cc/pulse/kg) of the exposed group is higher than that of control group (0.292 cc/pulse/kg body weight). To consider the adaptive mechanism which might operate at high altitude, the possibility is that the main limitations (HURTADO, 1964) arise in the diffusing capacity for oxygen in the pulmonary system and/or between muscle capillaries and tissues (WEST, 1962; WEST *et al.*, 1962). Increase of oxygen pulse can be stated as the rise of alveolar P_{O_2} due to hyperventilation of the Sherpa subjects at high altitude. Since the atmospheric P_{O_2} is lower at high altitude, the P_{O_2} in capillaries, and arterial and venous blood is also supposed to be lower. For Sherpas, having relatively lower pulmonary ventilation and lower pulse rate, it might be a compensation for increased amount of oxygen to enter from lung to blood.

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SOME ANTHROPOMETRIC STUDIES ON INDIANS IN A TROPICAL CLIMATE

by

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It is true that every individual has a bodily configuration as distinctive as his finger prints. It is, however, likely that the various aspects of the uniqueness of the individual can be overemphasized, thereby putting the inter-individual similarities in the background. If we consider the principles in support of the quantitative orderliness of physical constitution as developed by Adolph (1949), we cannot but appreciate nature's attempt to link the diversities.

It is stated (Scholander *et al.*, 1958; Coon, 1954, 1955) that there is a general tendency in animals to have their body form in accordance with the environmental condition in which they live. Wilber (1957) does not believe that with the influence of climate the body form of animals—including man—changes and he supports the views of Mayr (1956), McDowell *et al.* (1953) and Galineo (1955) in that readjustment of cellular mechanisms and not alterations of body form is the key factor in animal's adaptation to heat. Garn (1958) strongly criticized the views of Wilber (1957) and supported the views of Roberts (1953) and Adams (1958) in that the climatic rules (see Bergmann, 1847; Allen, 1887) do apply to man. An attempt was, therefore, made to throw some light on this controversy with reference to the Indians in a tropical climate.

A fairly comprehensive anthropometric measurement of a small number of the sample subjects from the eastern and western zone of India was taken in order to find out if there is a difference between the body measurements of people in the tropics and those of Westerners in cold climates.

METHODS

Fifteen normal male (aged 18-44 years) and seven female (aged 19-24 years) research and college adult students and nine schoolchildren (four girls and five boys, aged 3-10 years) who were naturally acclimatized in Calcutta, were selected at random and 31 different anthropometric measurements of their body as advocated by Du Bois and Du Bois (1915) were taken. Another sample of 40 adult male workers (aged 24-46 years) naturally acclimatized to the climate of Bombay were also selected at random. Fourty-one different anthropometric measurements according to Du Bois and Du Bois and 22 different other anthropometric measurements, generally used for machine design, were taken. Measurements were made on both the extremities and the mean value was recorded for each location.

Steel measuring tapes, linen measuring tapes, an anthropometer, a measuring board marked with horizontal and vertical lines, a stool with loose wooden plates, a calliper and a platform scale were used in the present study and each item was used accordingly with all the necessary precautions to obtain values which would be comparable with those of Westerners. The linen tape was manipulated in such a way as to avoid compression of the underlying tissues. All the measuring articles were calibrated against a standard metre scale. Linen measuring tapes were replaced immediately when a slight tendency of lengthening due to repeated use, was noted.

The detailed definitions of the different anthropometric measurements taken, are shown in Table 1.

RESULTS

Due to the relative paucity of such anthtropometric measurements on Indian subjects, all the anthropometric data of 15 adult male students, 40 adult male workers, 7 adult female students and 9 children, are given in Table 2 as the means with standard deviations and ranges, for the purpose of comparison. The differences in the measurements such as height, weight, etc., of the groups due to age and sex could easily be noted.

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Table 1A. Definitions of anthropometric measurements (according to Du Bois and Du Bois) used in the present investigation

Serial letter or no.	Item	Detailed definition
A	Vertex chin	Around vertex of head and point of chin.
B	Coronal	Coronal circumference around occiput and forehead, just above eyebrows.
F	Arm length	Tip of acromial process to lower border of radius measured with forearm extended.
G	Axilla arm	Circumference at the level of upper border of axilla.
H	Forearm (maximum)	Largest circumference of forearm (just below elbow).
I	Forearm (minimum)	Smallest circumference of forearm (just above the head of ulna).
J	Hand length	Lower posterior border of radius to the tip of second finger.
K	Open hand	Circumference of open hand at the metacarpophalangeal joints.
L	Suprasternal pubis	Suprasternal notch to upper border of pubes.
M	Abdomen	Circumference of abdomen at the level of umbilicus.
N	Chest (mid-tidal)	Circumference of thorax at the level of nipples in the male and just above breasts in the female.
O	Thigh length	Superior border of great trochanter to the lower border of patella.
P	Thigh circumference	Circumference of thigh just below the level of perineum.
Q	Hip circumference	Circumference of hips and buttocks at the level of great trochanters.
R	Patella length	From sole of foot to lower border of patella.
S	Patella circumference	Circumference at the level of lower border of patella.
T	Foot length	Length of foot including great toe.
U	Foot circumference	Circumference of foot at the base of little toe.
V	Ankle circumference	Smallest circumference of ankle (just above malleoli).
I	Weight	Weight of the body without clothes.
II	Height	Height to vertex.
III	Suprasternal foot	Sole of foot to suprasternal notch.
IV	Nipples-foot	Sole of foot to level of nipples.
V	Axilla-foot	Sole of foot to upper border of axilla.
VI	Ensiform-foot	Sole of foot to tip of ensiform process.
VII	Trochanter-foot	Sole of foot to superior border of great trochanter.
VIII	Perineum-foot	Sole of foot to perineum.
IX	Trunk circumference	Circumference of body (trunk) at level of tip of ensiform process.
X	Arm length	Tip of second finger to upper border of axilla.
XI	Finger-olecranon	Tip of second finger to tip of olecranon process.
XII	Finger-metacarpo	Tip of second finger to metacarpophalangeal process.
XIII	Forearm length	Tip of olecranon to lower border of radius.
XIV	Upper arm length	Tip of olecranon to acromial process.
XV	Upper arm circumference	Circumference of arm at the insertion of the deltoid.
XVI	Biceps circumference	Circumference of arm at belly of biceps.
XVII	Mid thigh circumference	Circumference of thigh half-way between anterior superior spine of the ilium and the lower border of patella.
XVIII	Calf circumference (maximum)	Largest circumference of calf.
XIX	Around heel	Circumference of foot around heel.
XX	Around maxilla	From back of neck around superior maxilla just below ears and nose.
XXI	Neck circumference	Around neck just below larynx.
XXII	Shoulder circumference	Around shoulders at level of heads of humeri.

Table 1B. Measurements while sitting (Sacrum pressed on the board, elbow and knee at right angles, erect position)

Serial no.	Measurement	Details
1	Buttock-knee	Right side, trunk erect, knees together and knee angle at right angles, thighs horizontal, contact measurement, buttock to skin over patella (knee-cap).
2	Seat length	Knee at right angles, feet rested flat on floor. Buttock to back of the knee (posterior aspect of leg).
12	Leg length	Seated on the floor, sacrum against the board, legs fully extended, feet at right angles to legs. Distance from feet to board.
4	Elbow-seat	Upper arm and forearm at right angles. Back against the board ; distance between elbow and seat.

Table 1B (continued)

Serial no.	Measurement	Details
3	Patella height	Leg at right angles to thigh. Measure from top of muscle mass near end of femur to floor (heels).
6	Seat height	Feet rested flat on floor; knee at right angles. Distance between floor and lower surface of thigh behind the knee.
5	Shoulder-elbow	Trunk erect, humerus vertical, forearm horizontal. Measure from top of acromion process to bottom of elbow.
7	Sitting height	Back against the board until back of knee touches the stool edge, legs dangling freely. Trunk as erect as possible; head in eye-ear horizontal. Measure from rear between top of head and stool.
8	Trunk height	Trunk same as in sitting height. Distance from stool to topmost margin of body sternum palpated disregarding supra-sternal bones. Measured from front.
9	Back height	Seat erect as in sitting height. Distance from stool to groove between first and second vertebra. Measure from back.
10	Abdominal depth	Maximum horizontal contact dimension, wherever found.
11	Chest depth	Horizontal anteroposterior dimension at nipple level. Contact from spinal groove to sternum.

Table 1C. Measurement while standing erect (from side)

Serial no.	Measurement	Details
13	Anterior arm reach	Heels together; heels, buttock middle of back and occiput against the board. Now both arms horizontal in maximum forward reach with contacts maintained.
14	Crotch height	Vertical distance from crotch to floor.
15	Foot length	Weight even on both feet. Left foot, maximum contact from heel to great toe (or second toe if longer).
16	Foot breadth	Position as 15; measure maximum breadth.

Table 1D. Measurements while standing erect (from front)

Serial no.	Measurement	Details
21	Bi-trochanteric	Knees together and at right angles, trunk erect. Maximum lateral diameter of buttocks, light touch measurements.
17	Height	Heels together, feet at right angles, body erect; distance from top of head to floor.
19	Span akimbo	Arms flexed, held horizontally palms down, fingers straight and together, thumbs touching chest, wrists straight, fingers of each hand not meeting. Distance between two elbow points.
18	Total span	Arms stretched on sides distance between tips of middle fingers.
23	Bi-deltoid	Arms at side, palms forward; maximum contact dimension across deltoids.
22	Bi-illiac	Heels together, a firm pressure dimension of maximum illiac brim (across hip bones).
20	Forearm length	Distance from elbow tip to the tip of middle finger when arm is flexed at elbow.
24	Hand length	Distance from end of small wrist bone at base of thumb to tip of middle finger where hand is stretched.
25	Chest circumference (rest)	Horizontal circumference just above nipples. Tape not tightened but merely in contact all round; chest neither collapsed nor expanded; taken during quiet breathing.
26	Circumference of head	Top maximum circumference.
27	Circumference of upper arm	Maximum of biceps.
28	Circumference of forearm	At half-way between elbow and wrist.
29	Circumference of thigh	At half-way between crotch and knee (left leg).
30	Maximum distance around left calf	Maximum distance around left calf.

Table 3 shows the comparison of different other body measurements of the 40 Indian workers with those of the 499 Indian workers.[1] Since the 499 Indian workers (aged 19-60 years, with mean 37.3 years) was not a homogeneous group, the whole group was divided into sub-groups of people from Maharashtra, Uttar Pradesh and South India (rest). The different measurements for the different groups are given in Table 4. The results show negligible differences among the groups. The values for the different anthropometric measurements of the Indian subjects are compared with those of the Westerners in Table 5. Where the original source did not cite metric units, the values were multiplied by the proper conversion factor. Where the same or approximately the same measurements were given for different groups, they were all entered in the proper columns for the purpose of comparison. The precise definition of any particular measurement was carefully examined and only comparable values were entered. It will be observed from Table 5 that there are marked differences in the different body measurements of Indians in a tropical climate as compared to those of Westerners in a cold climate. Not only the average weight, height and other body measurements of the Indians are much lower than the values of Westerners, but the differences for the different regions are also not proportionate. If we compare the different linear measurements as proportions of height as given in Table 6, we find thas the trunk and sitting heights of the Indians are proport tionately less than those of Westerners, wherea the-lengths of the peripheral parts (upper and lower extremities) are proportionately more, indicating relative enlargement of the peripheral parts of the body of Indian subjects. When circumferences and diameters of different regions of the body are expressed as gramme weight per centimetre height, it shows also the evidence of the relative enlargement of the peripheral parts in the case of the Indians.

1. Unpublished work of the Physiology Division, Central Labour Institute, Bombay.

TABLE 2. Different anthropometric measurements taken (according to Du Bois and Du Bois) for Indian subjects[1]

Serial no. or letter	Measurements	East Indian (Bengal) adult males (students) (N = 15)		West Indian (Bombay) adult males (workers) (N = 40)		East Indian (Bengal) adult females (students) (N = 7)		East Indian (Bengal) children (students) (N = 9; 4 girls, 5 boys)	
		Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation
A	Vertex-chin circumference	66.15	3.03	64.19	2.45	63.71	2.89	57.38	1.40
		(61.9-70.8)[2]		(56.3-67.0)		(60.8-66.7)		(54.3-62.1)	
B	Coronal circumference	54.79	2.25	55.24	1.34	53.60	2.63	49.11	2.11
		(52.6-58.1)		(51.6-58.0)		(51.0-56.9)		(46.7-52.6)	
F	Arm length	56.33	3.43	57.95	3.78	50.24	2.17	34.42	3.94
		(51.6-65.2)		(52.9-71.1)		(48.2-51.1)		(26.9-42.0)	
G	Axilla arm circumference	26.83	2.91	29.93	2.59	26.97	2.05	16.94	1.72
		(23.9-32.7)		(23.2-38.5)		(24.5-29.1)		(14.9-20.0)	
H	Forearm circumference (largest)	23.23	1.77	24.61	1.09	21.96	1.03	15.96	1.13
		(21.2-27.1)		(22.2-27.0)		(20.7-23.6)		(14.0-18.4)	
I	Forearm circumference (smallest)	14.51	1.09	15.56	0.80	14.74	1.04	10.90	0.72
		(13.0-16.8)		(13.8-17.2)		(13.5-15.8)		(9.8-12.3)	
J	Hand length	17.34	1.09	19.11	1.13	16.67	0.63	11.86	1.07
		(15.6-19.3)		(16.5-23.7)		(16.0-17.0)		(10.1-14.1)	
K	Open hand circumference	19.31	1.05	20.38	1.39	18.01	0.79	13.96	0.61
		(18.1-21.1)		(18.3-26.7)		(17.2-18.4)		(12.4-15.4)	
L	Suprasternal-pubis	51.39	2.84	53.62	3.18	50.07	2.79	36.39	3.36
		(46.4-57.0)		(47.8-62.0)		(46.0-53.5)		(30.4-44.5)	
M	Abdomen circumference	65.65	2.73	72.91	1.86	74.69	7.27	48.27	4.01
		(59.4-87.9)		(62.0-90.2)		(73.4-87.0)		(41.4-57.5)	
N	Chest (mid-tidal)	81.03	2.15	84.29	5.76	80.49	3.30	54.24	3.86
		(71.1-96.8)		(72.3-100.2)		(77.1-84.0)		(45.7-62.6)	
O	Thigh length	42.49	2.31	42.96	3.56	41.86	2.03	27.34	3.80
		(39.5-46.1)		(36.2-53.3)		(40.0-43.5)		(21.3-35.7)	
P	Thigh circumference	48.48	4.96	49.15	3.11	54.77	5.80	31.51	3.66
		(42.2-56.7)		(42.8-58.0)		(50.2-66.4)		(25.7-40.1)	
Q	Hip circumference	83.98	5.31	85.94	5.32	88.81	6.30	52.41	5.60
		(78.4-90.2)		(77.3-98.3)		(83.0-99.8)		(42.2-64.9)	
R	Patella length	45.81	3.15	46.29	3.02	42.56	3.12	29.62	3.82
		(41.0-51.8)		(40.2-56.5)		(38.0-46.5)		(23.9-38.4)	

Table 2 (continued)

Serial no. or letter	Measurements	East Indian (Bengal) adult males (students) (N = 15)		West Indian (Bombay) adult males (workers) (N = 40)		East Indian (Bengal) adult females (students) (N = 7)		East Indian (Bengal) children (students) (N = 9; 4 girls, 5 boys)	
		Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation
S	Patella circumference	31.17	2.17	30.78	1.73	31.97	2.24	21.99	2.08
		(28.3-37.2)		(27.8-36.2)		(29.0-35.7)		(19.0-26.8)	
T	Foot length	23.91	1.31	24.29	1.34	22.04	1.05	16.51	1.80
		(21.7-25.9)		(20.0-27.6)		(20.6-23.0)		(13.1-20.3)	
U	Foot circumference	22.49	1.09	23.04	1.98	21.16	0.90	16.46	1.26
		(21.4-24.8)		(20.0-32.0)		(21.1-22.1)		(14.6-19.7)	
V	Ankle circumference	20.11	1.36	19.72	1.40	19.87	1.34	14.29	1.03
		(18.4-21.7)		(17.2-22.8)		(18.7-21.8)		(12.4-16.7)	
I	Weight (kg.)	49.56	8.53	54.71	6.54	46.73	5.24	16.57	4.33
		(36.5-66.8)		(43.1-74.9)		(40.4-55.1)		(10.3-27.2)	
II	Height	163.00	7.78	164.40	4.92	153.31	8.12	108.53	12.50
		(151.9-176.1)		(154.5-173.0)		(142.0-160.1)		(88.2-137.3)	
III	Suprasternal-foot	136.02	6.95	138.96	5.06	128.64	6.94	115.8	10.99
		(123.7-149.3)		(130.8-152.2)		(119.0-134.0)		(72.2-115.8)	
IV	Nipples-foot	126.31	6.46	128.67	4.66	119.50	6.96	81.92	12.37
		(116.1-138.0)		(119.1-130.1)		(110.0-125.0)		(57.2-108.2)	
V	Axilla-foot	130.18	6.91	132.85	8.25	124.23	6.42	85.44	11.55
		(119.8-141.6)		(105.1-149.8)		(115.0-130.0)		(67.6-111.2)	
VI	Ensiform-foot	119.39	6.40	120.83	5.60	111.83	5.97	77.77	9.54
		(118.8-130.8)		(107.3-134.6)		(104.5-117.0)		(62.4-100.6)	
VII	Trochanter-foot	88.14	5.13	87.32	4.07	82.29	3.79	57.12	7.45
		(80.7-97.9)		(79.4-97.3)		(78.0-86.0)		(45.2-73.1)	
VIII	Perineum-foot	78.91	4.98	85.98	4.37	77.93	4.20	53.11	7.46
		(70.9-86.9)		(77.2-98.1)		(72.0-83.5)		(42.0-70.8)	
IX	Trunk circumference	76.61	6.19	80.88	4.65	72.03	5.44	54.80	2.96
		(67.0-91.5)		(70.2-96.2)		(64.0-78.9)		(48.2-61.4)	
X	Arm length	63.23	3.39	67.40	4.98	59.86	3.16	40.44	4.77
		(58.1-69.3)		(61.6-83.0)		(56.0-63.0)		(32.1-48.8)	
XI	Finger-olecranon	44.01	2.52	46.84	1.37	40.47	2.05	28.76	3.23
		(40.6-48.8)		(43.5-50.8)		(38.0-42.6)		(22.6-34.9)	
XII	Finger-metacarpo	9.99	0.46	10.36	0.59	9.31	0.66	6.77	0.56
		(9.2-11.0)		(9.2-12.2)		(8.5-10.0)		(5.9-8.0)	
XIII	Forearm length	26.61	1.68	28.33	1.45	24.76	1.05	17.68	2.25
		(24.8-30.2)		(25.7-31.8)		(23.7-25.9)		(13.9-22.4)	
XIV	Upper arm length	30.11	2.57	35.08	1.87	27.90	1.84	19.31	2.39
		(26.8-35.0)		(28.0-38.1)		(25.5-29.5)		(15.5-24.8)	
XV	Upper arm circumference	25.58	2.99	27.08	2.38	24.90	1.52	15.99	1.50
		(22.4-31.4)		(23.5-32.8)		(23.1-27.4)		(14.0-18.4)	
XVI	Biceps circumference	23.39	2.77	25.07	1.60	23.96	2.65	15.60	1.22
		(20.3-29.7)		(21.6-29.9)		(21.1-29.1)		(13.6-17.5)	
XVII	Mid thigh circumference	43.95	3.81	45.55	2.90	48.84	4.88	29.76	3.13
		(38.7-49.9)		(41.2-52.5)		(42.9-58.5)		(25.4-35.9)	
XVIII	Calf circumference (largest)	31.63	2.80	30.47	2.29	32.03	2.31	21.76	3.33
		(28.0-37.7)		(22.4-36.2)		(29.8-33.7)		(18.1-24.2)	
XIX	Around heel	30.36	1.74	31.63	2.44	27.16	1.89	21.78	2.37
		(28.6-33.6)		(23.3-41.1)		(24.0-29.0)		(17.7-27.5)	
XX	Around maxilla	48.25	2.94	47.74	4.20	45.17	2.30	38.54	2.37
		(44.4-54.6)		(32.5-57.5)		(41.5-46.9)		(34.3-44.0)	
XXI	Neck circumference	34.24	2.90	36.64	3.39	31.99	1.49	23.37	3.07
		(30.1-40.6)		(27.9-46.7)		(30.2-33.2)		(15.5-27.4)	
XXII	Shoulder circumference	—		101.6	5.57	80.99	6.02	59.04	4.44
				(92.5-130.0)		(72.6-88.9)		(49.5-68.3)	
	Age (yrs.)	24.07	6.23	33.29	6.95	20.85	2.33	5.83	1.93
		(18-44)		(24-46)		(19-24)		(3-10)	

1. Measurements are given in centimetres unless otherwise indicated.
2. Figures in parentheses indicate range.

TABLE 3. Different anthropometric measurements of Indian adult male workers in Bombay[1]

Serial no.	Anthropometric measurements	Adult male workers (N = 40)			Adult male workers (N = 499)		
		Mean	Standard deviation	Range	Mean	Standard deviation	Range
1	Buttock-knee	54.89	2.66	50.0- 59.8	55.32	2.61	46.0- 62.3
2	Seat length	45.64	2.75	37.5- 51.0	46.62	2.41	36.3- 53.0
3	Patella height	51.33	2.41	47.2- 55.5	51.18	2.41	46.5- 57.8
4	Elbow-seat	22.98	2.10	18.0- 26.5	21.79	2.18	16.3- 28.3
5	Shoulder-elbow	36.13	2.14	25.5- 39.0	35.83	2.18	30.5- 41.5
6	Seat height	41.95	1.61	39.0- 45.0	40.30	1.50	34.0- 46.5
7	Sitting height	86.22	2.83	80.0- 91.0	85.10	3.04	75.0- 94.0
8	Trunk height	56.26	2.43	52.0- 61.0	54.46	2.65	47.0- 63.0
9	Back height	62.45	2.70	56.5- 68.5	60.18	2.74	52.5- 69.0
10	Abdominal depth	18.44	2.34	15.0- 27.0	19.42	2.11	15.4- 32.8
11	Chest depth	17.58	1.44	14.8- 22.5	18.25	1.69	14.4- 25.3
12	Leg length	104.30	6.02	94.0-116.0	102.98	4.80	86.0-116.0
13	Anterior arm reach	82.76	3.40	76.0- 90.0	83.48	3.79	71.8- 96.8
14	Crotch height	70.86	4.11	60.0- 78.0	75.78	4.19	60.0- 88.5
15	Foot length	24.29	1.34	20.0- 27.6	24.73	1.16	21.6- 29.7
16	Foot breadth	9.62	0.47	8.5- 10.5	10.24	0.43	8.7- 11.4
17	Height	164.40	4.92	154.5-173.0	163.00	6.10	142.0-182.8
18	Total span	169.80	8.12	157.0-187.8	169.45	7.25	148.4-193.6
19	Span akimbo	86.34	3.74	76.5- 93.5	86.50	3.68	75.8-100.0
20	Forearm length (includ-ind hand)	46.84	1.37	43.5- 50.8	45.51	1.97	40.0- 51.5
21	Bitrochanteric	29.16	1.54	26.5- 32.8	28.99	1.61	24.9- 35.6
22	Bi-iliac	24.98	1.57	21.5- 28.5	24.63	1.53	19.0- 30.3
23	Bi-deltoid	39.88	2.16	38.0- 45.0	40.17	1.91	33.7- 44.9
24	Hand length	19.11	1.13	16.5- 23.7	18.67	0.88	15.4- 21.3
25	Chest circumference (mid-tidal)	84.29	5.76	72.3-100.2	83.70	5.65	69.7-103.2
26	Head circumference	55.24	1.34	51.6- 58.0	53.96	1.57	49.7- 59.3
27	Upper arm circumference	27.08	2.38	23.5- 32.8	25.12	2.68	18.4- 33.4
28	Forearm circumference	24.61	1.09	22.2- 27.0	20.66	1.59	16.5- 25.4
29	Thigh circumference	45.55	2.90	41.2- 52.5	40.34	3.75	31.0- 56.3
30	Calf circumference	30.47	2.29	22.4- 36.2	30.50	2.36	24.7- 40.2
31	Body weight (kg.)	54.71	6.54	43.1- 74.9	50.85	8.00	31.5- 86.5
32	Wrist diameter	5.08	0.23	4.4- 5.4	—	—	—
33	Knee diameter	9.03	1.52	8.3- 10.2	—	—	—

1. Measurements are given in centimetres unless otherwise indicated.

TABLE 4. Different anthropometric measurements of workers in textile mills in Bombay[1]

Serial no.	Anthropometric measurements	Subjects: All (N = 499)		Maharashtra (N = 370)		Uttar Pradesh (N = 90)		Rest (N = 39)	
		Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation
1	Buttock-knee	55.32	2.61	55.12	2.54	55.94	2.76	55.52	2.30
2	Seat length	46.62	2.41	46.40	2.78	47.29	2.52	47.10	2.18
3	Patella height	51.18	2.41	51.08	2.26	51.08	2.06	51.66	1.84
4	Elbow-seat	21.79	2.18	21.81	2.18	21.97	2.10	21.27	2.41
5	Shoulder-elbow	35.83	2.18	35.59	1.62	35.76	1.92	36.01	1.41
6	Seat height	40.30	1.50	40.24	1.43	40.47	1.88	40.53	1.14
7	Sitting height	85.10	3.04	85.08	3.00	85.46	3.42	84.52	3.38
8	Trunk height	54.46	2.65	54.44	2.48	54.86	2.72	53.94	2.78
9	Back height	60.18	2.74	60.06	2.72	60.68	2.54	60.02	2.42
10	Abdominal depth	19.42	2.11	19.42	2.14	19.36	1.68	19.54	2.58

Table 4 (continued)

Serial no.	Anthropometric measurements	Subjects: All (N = 499) Mean	Standard deviation	Maharashtra (N = 370) Mean	Standard deviation	Uttar Pradesh (N = 90) Mean	Standard deviation	Rest (N = 39) Mean	Standard deviation
11	Chest depth	18.25	1.69	18.10	2.21	18.64	1.51	18.03	1.72
12	Leg length	102.98	4.80	102.78	4.74	103.32	5.08	104.12	4.50
13	Anterior arm reach	83.48	3.79	83.16	3.78	84.46	3.96	84.36	2.84
14	Crotch length	75.78	4.19	75.72	4.20	75.58	4.66	76.74	3.94
15	Foot length	24.73	1.16	24.65	1.14	25.06	1.24	24.81	0.85
16	Foot breadth	10.24	0.43	10.21	0.46	10.34	0.48	10.26	0.40
17	Height	163.00	6.10	163.00	6.00	163.10	6.70	163.75	5.70
18	Total span	169.45	7.25	170.00	6.40	171.30	8.05	168.55	8.25
19	Span akimbo	86.50	3.68	86.68	4.32	87.54	4.06	87.54	3.28
20	Forearm length	45.51	1.97	45.35	1.93	45.78	1.93	47.04	1.81
21	Bi-trochanteric	28.99	1.61	28.87	1.65	29.50	1.50	28.91	1.72
22	Bi-iliac	24.63	1.53	24.58	1.47	24.82	1.71	24.35	1.72
23	Bi-deltoid	40.17	1.91	39.65	2.21	40.31	1.87	40.32	2.00
24	Hand length	18.67	0.88	18.56	0.87	18.89	0.93	18.65	0.83
25	Chest circumference (mid-tidal)	83.70	5.65	83.40	5.39	85.05	5.25	83.95	5.70
26	Circumference of head	53.96	1.57	53.88	1.51	54.24	1.62	54.29	1.81
27	Circumference of upper arm	25.12	2.68	25.08	1.51	25.06	2.48	24.74	2.44
28	Circumference of forearm	20.66	1.59	20.81	1.67	20.64	1.45	20.63	1.37
29	Circumference of thigh	40.34	3.72	40.60	3.74	39.46	3.46	39.62	3.46
30	Circumference of calf	30.50	2.36	30.68	2.42	29.96	2.10	30.44	2.40
31	Body weight (kg.)	50.85	8.00	50.60	8.15	51.60	8.85	50.60	8.15

1. Measurements are given in centimetres unless otherwise indicated.

Table 5. Comparison between different anthropometric measurements of Indian adult males in tropical climates and those of Westerners in cold climates

Reference	Measurements[1]	Source[2]	No. and type of subjects	Age (years)	Mean	Standard deviation	Range
I.31	Weight (kg.)	*	15 Indian students	18-44	49.56	8.53	36.5-66.8
		*	40 Indian workers	24-46	54.71	6.54	43.1- 74.9
		1	499 Indian workers	19-60	50.85	8.00	31.5- 86.5
		2	584 American gunners		66.72	7.17	49.0- 92.1
		3	103 American drivers	34.1	75.80	12.27	—
		4	31 American naval personnel	20-40	78.30	—	—
		5	63 British naval personnel	18.29	66.34	6.41	—
		6	529 British pilots and gunners	23.2	65.73	7.21	—
II.17	Height	*	15 Indian students	18-44	163.00	7.78	151.9-176.1
		*	40 Indian workers	24-46	164.40	4.92	154.5-173.0
		1	499 Indian workers	19-60	163.00	6.10	142.0-182.8
		2	584 American gunners		172.41	4.21	150.9-188.7
		3	103 American drivers	34.1	175.20	5.79	—
		4	31 American naval personnel	20-40	178.30	—	—
		5	63 British naval personnel	18-29	173.20	6.47	—
		6	529 British pilots and gunners	23.2	172.70	6.02	—
7	Sitting height	*	40 Indian workers	24-46	86.22	2.83	80.0- 91.0
		1	499 Indian workers	19-60	85.10	3.04	75.0- 94.0
		2	584 American gunners	—	91.18	2.01	82.0-100.1
		3	103 American drivers	34.1	93.00	2.69	—
		5	63 British naval personnel	18-29	89.80	3.37	—
		6	529 British pilots and gunners	23.2	91.9	3.15	—
13	Anterior arm reach	*	40 Indian workers	24-48	82.76	3.40	76.0- 90.0
		1	499 Indian workers	19-60	83.48	3.78	71.8- 96.8
		2	580 American gunners	—	88.34	2.75	74.9- 99.1

Table 5 (continued)

Reference	Measurements[1]	Source[2]	No. and type of subjects	Age (years)	Mean	Standard deviation	Range
18	Total span	*	40 Indian workers	24-46	169.80	8.12	157.0-187.8
		1	499 Indian workers	19-60	169.45	7.25	148.0-193.6
		2	584 American gunners	—	179.04	5.03	153.9-201.9
		5	63 British naval personnel	18-29	181.00	6.85	—
8	Trunk height	*	40 Indian workers	24-46	56.26	2.43	52.0- 61.0
		1	499 Indian workers	19-60	24.46	2.65	47.-0 63.0
		2	583 American gunners	—	59.14	1.63	51.1- 66.0
III	Suprasternal height	*	15 Indian students	18-44	136.02	6.95	123.7-149.3
		*	40 Indian workers	24-46	138.96	5.06	130.8-152.2
		5	60 British naval personnel	18-29	140.70	5.71	—
VI	Ensiform height	*	15 Indian students	18-44	119.39	6.40	118.8-130.8
		*	40 Indian workers	22-46	120.83	5.60	107.3-134.6
		5	59 British naval personnel	18-29	122.20	5.06	—
J + XIII + XIV	Upper extremity	*	15 Indian students	18-44	74.06	1.78	67.2- 84.5
		*	40 Indian workers	24-46	82.52	1.48	70.2- 93.6
		5	60 British naval personnel	18-29	78.20	1.32	—
J.24	Hand length	*	15 Indian students	18-44	17.34	1.09	15.6- 19.3
		*	40 Indian workers	24-46	19.11	1.13	16.5- 23.7
		1	499 Indian workers	19-60	18.67	0.88	15.4- 21.3
		5	59 British naval personnel	18-29	19.60	0.83	—
VII	Trochanteric height	*	15 Indian students	18-44	88.14	5.13	80.7- 97.9
		*	40 Indian workers	24-46	87.32	4.07	79.4- 97.3
		5	59 British naval personnel	18-29	87.20	4.51	—
14	Crotch height	*	40 Indian workers	24-46	70.86	4.11	60.0- 78.5
		1	499 Indian workers	19-60	75.78	4.19	60.0- 88.5
		7	2691 American cadets	—	82.20	—	—
12	Leg length	*	40 Indian workers	24-46	104.30	6.02	94.0-116.0
		1	499 Indian workers	19-60	102.98	4.80	86.0-116.0
		8	163 American students	—	104.39	4.57	—
15.T	Foot length	*	15 Indian students	18-44	23.91	1.31	21.7 -25.9
		*	40 Indian students	24-46	24.29	1.34	20.0 -27.6
		1	499 Indian workes	19-60	24.73	1.16	21.6- 29.7
		2	583 American gunners	—	26.33	0.80	22.9- 30.0
11	Chest depth	*	40 Indian workers	24-46	17.58	1.44	14.8- 22.5
		1	499 Indian workers	19-60	18.25	1.69	14.4- 25.3
		2	583 American gunners	—	20.69	1.06	15.0- 26.9
		5	63 British naval personnel	18-29	20.40	1.61	—
10	Abdominal depth	*	40 Indian workers	24-46	18.44	2.34	15.0- 27.0
		1	499 Indian workers	19-60	19.42	2.11	15.4- 32.8
		2	584 American gunners	—	20.71	1.07	16.0- 36.1
32	Wrist diameter	*	40 Indian workers	24-46	5.08	0.23	4.4- 5.4
		4	31 American naval personnel	20-40	5.55	—	—
22	Bi-iliac	*	40 Indian workers	24-46	24.98	1.57	21.5- 28.5
		1	499 Indian workers	19-60	24.63	1.53	19.0- 30.3
		2	584 American gunners	—	28.60	1.09	23.9- 34.0
		4	31 American naval personnel	20-40	28.60	—	—
		5	63 British naval personnel	18-29	28.60	1.91	—
21	Bi-trochanteric	*	40 Indian workers	24-46	29.16	1.54	26.5- 32.8
		1	499 Indian workers	19-60	28.99	1.61	24.9- 35.6
		2	583 American gunners	—	35.09	1.34	31.0- 41.9
		4	31 American naval personnel	20-40	32.80	—	—
33	Knee diameter	*	40 Indian workers	24-46	9.03	1.52	8.3- 10.2
		4	31 American naval personnel	20-40	9.25	—	—
16	Foot breadth	*	40 Indian workers	24-46	9.62	0.47	8.5- 10.5
		1	499 Indian workers	19-60	10.24	0.43	8.7- 11.4
		5	59 British naval personnel	18-29	9.60	0.44	—
26	Head circumference	*	40 Indian workers	24-46	55.24	1.34	51.6- 58.0
		1	499 Indian workers	19-60	53.96	1.57	49.7- 59.3
		2	584 American gunners	—	56.37	2.22	51.0- 60.0
		9	196 American pilots	—	57.47	2.63	54.0- 61.2
25.N	Chest circumference (mid-tidal)	*	15 Indian students	18-44	81.03	2.15	71.1- 96.8

Table 5 (continued)

Reference	Measurements[1]	Source[2]	No. and type of subjects	Age (years)	Mean	Standard deviation	Range
		*	40 Indian workers	24-46	84.29	5.76	72.3-100.2
		1	499 Indian workers	19-60	83.70	5.65	69.7-103.2
		2	584 American gunners	—	90.05	3.26	78.0-103.9
		9	184 American pilots	—	91.95	—	—
		5	61 British naval personnel	18-29	87.20	5.05	—
27.XVI	Upper arm circumference	*	15 Indian students	18-44	23.39	2.77	20.3- 29.7
		*	40 Indian workers	24-46	25.07	2.38	23.5- 32.8
		1	499 Indian workers	19-60	25.12	2.68	18.4- 33.4
		5	62 British naval personnel	18-29	27.80	2.04	—
28.H	Forearm circumference (maximum)	*	15 Indian students	18-44	23.23	1.77	21.2- 27.1
		*	40 Indian workers	24-46	24.61	1.09	22.2- 27.0
		1	499 Indian workers	19-60	20.66	1.59	16.5- 25.4
		5	62 British naval personnel	18-29	26.70	1.30	—
I	Forearm circumference (minimum)	*	15 Indian students	18-44	14.51	1.09	13.0- 16.8
		*	40 Indian workers	24-46	15.56	0.80	13.8- 17.2
		5	63 British naval personnel	18-29	17.60	1.66	—
P	Thigh circumference (maximum)	*	15 Indian students	18-44	48.48	4.96	42.2- 56.7
		*	40 Indian workers	24-46	49.15	3.11	42.8- 58.0
		5	63 British naval personnel	18-29	53.00	3.24	—
30.XVIII	Calf circumference (maximum)	*	15 Indian students	18-44	31.63	2.80	28.0- 37.7
		*	40 Indian workers	24-46	30.47	2.29	22.4- 36.2
		1	499 Indian workers	19-60	30.50	2.36	24.7- 40.2
		5	63 British naval personnel	18-29	35.60	2.09	—

1. Measurements are given in centimetres unless otherwise indicated.
2. Sources: * This article; 1. Central Labour Inst., Bombay; 2. Randall *et al.* (1946); 3. McFarland *et al.* (1953); 4. Taylor and Behnke (1961); 5. Roberts (1957); 6. Morant and Gilson (1945); 7. Randall (1943); 8. Elbel (1945); 9. Benton (1943).

Table 6. Comparison between different linear measurements as proportionate of height of Indians and Westerners[1]

No.	Measurements	Indian students (N = 15)	Indian workers (N = 40)	Indian workers (N = 499)	American gunners (N = 584)	American drivers (N = 103)	British naval personnel (N = 63)	British pilots and gunners (N = 529)
	Lengths							
7	Sitting height	—	0.525	0.522	0.529	0.531	—	0.532
8	Trunk height	—	0.318	0.334	0.343	—	—	—
J + XIII + XIV	Upper extremity	0.455	0.502	—	—	—	0.451	—
24	Hand length	—	0.116	0.115	—	—	0.113	—
VII	Trochanteric height	0.541	0.531	—	—	—	0.503	—
12	Leg length	—	0.634	0.632	—	0.588[2]	—	—
	Comparison of different diameters and circumferences as per gm. body weight per cm. height							
	Diameters							
11	Chest depth	—	0.053	0.059	0.054	—	0.054	—
32	Wrist	—	0.015	—	—	—	0.012	—
33	Knee	—	0.027	—	—	0.021[3]	—	—
	Circumferences							
N	Chest	0.267	0.253	0.268	0.232	—	0.228	—
XVI	Upper arm	0.077	0.075	0.081	—	—	0.073	—
H	Forearm (maximum)	0.076	0.074	0.066	—	—	0.069	—
P	Thigh	0.159	0.157	—	—	—	—	0.138

1. Sources were: 15 Indian students (this article); 40 Indian workers (this article); 499 Indian workers (Central Labour Inst., Bombay); 584 American gunners (Randall *et al.*, 1946); 103 American drivers (McFarland *et al.*, 1953); 63 British naval personnel (Roberts, 1957); 529 British pilots and gunners (Morant and Gilson, 1945).
2. Figure for 163 American students (Elbel, 1945).
3. Figure for 31 American naval personnel (Taylor and Behnke, 1961).

DISCUSSION

It is rather surprising that anthropometric data for comparative purposes are difficult to obtain. Many of the figures for the purpose of comparison have to be taken from literature where the values were obtained from measurements based upon a somewhat selected population, e.g., various service groups. Since these groups are to be within certain defined maxima and minima, the tails of the "normal curve" for an unselected population are certainly cut off. This was always kept in mind while comparing the data. Although there will be some error in the values of the standard deviation and the range, the error in the value of the mean is probably not large.

From Table 5, it will be observed that there are marked differences in the body form of Indians in the tropics as compared to that of the Westerners in cold climates. There is a tendency for the people in the tropics to have a body form of the "ectomorphic" type, being more skinny and of less body weight. In a hot, humid, tropical climate the human body must be able to maintain its temperature. Therefore, either it must have a lesser amount of energy-producing organ and hence less weight of visceral organ or it must have a more radiating or evaporative surface to increase heat dissipation. When the average body weight of a person living in the tropics is reduced, due to the evolutionary effect of the climate, the supporting structures, such as the legs, etc., need not remain large in girth but could become slender in order to have a more effective evaporative surface per unit weight of the body or the length or breadth of the peripheral parts may be relatively larger to increase the effective surface area of the body.

The surface area of the Indian adult male and female students of the present study was actually measured (Banerjee and Sen, 1955, 1957; Banerjee *et al.*, 1958) and it was found that the total surface area of the body of each subject was more than that calculated by the weight-height formula of Du Bois and Du Bois (1916). The present author actually measured the surface area of nine Indian children for the present study, and observed the surface area of the body in each case to be greater than that calculated with the weight-height formula. It is to be noted that the corrected constant in the weight-height formula was more in Indian adult females (78.28) than in the males (74.66). It may be due to the lower average height in proportion to weight of the body in the former and also due to the adaptation of the body of the females in the tropics to provide more surface for evaporation needed to help heat dissipation which is hindered by the greater proportion of fat in the body of adult females than that in adult males as was found by the present author (Sen and Banerjee, 1958). When the percentage ratio of the measured surface area of each component region of the body was compared to the surface area of the whole body, it was found that the percentage was greater for the extremities and smaller for the trunk in the case of Indians, when compared with the subjects of Du Bois and Du Bois (1915).

There is a good agreement that the basal heat production in Indians in a tropical climate is lower than that in Westerners in cold climates. The present author (Sen and Banerjee, 1958) observed that basic metabolic rate of Indians is on the average from 12 to 17 per cent lower than the universally accepted Mayo Foundation Standards for the Westerners. It was also observed by the author (Banerjee and Sen, 1958) that a large part of the difference of the basal oxygen consumption between Indians and Westerners could be accounted for when the values are expressed per kg. of cell solids or cell mass or lean body mass.

From these observations, it may be concluded that both the body form and readjustments of cellular mechanisms are equally important adaptation processes of the body to maintain its temperature in tropical climates. The reduction in heat production constitutes an important economy of energy expenditure and is of great significance in the continued existence of the organism in a tropical environment. Similarly the change in the body form to provide a larger surface for evaporation is an important step towards the process of heat dissipation in a tropical climate.

SUMMARY

Forty-one different anthropometric measurements as suggested by Du Bois and Du Bois were taken on 31 normal naturally acclimatized subjects consisting of 15 adult male and seven adult female students and nine children of the eastern zone of India. In addition to these measurements 22 different other anthropometric measurements were also taken on 40 naturally acclimatized Indian workers of the western zone.

The values were compared with those of Westerners. Significant difference between the body form of the people in tropical country and that of the people in cold climates was observed.

This was presumed to be the effect of tropical climate in providing for greater evaporative or radiating surface and lesser heat producing cell mass.

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RÉSUMÉ

Quelques études anthropométriques faites sur des sujets indiens en climat tropical (R. N. Sen)

On a procédé, suivant la suggestion de Du Bois et Du Bois, à 41 mensurations anthropométriques distinctes sur 31 sujets normaux : 15 hommes, 7 femmes et 9 enfants, tous originaires de la partie orientale (Bengale) de l'Inde, pour déterminer les effets anatomiques du « stress » thermique auquel le climat local soumet constamment l'organisme.

Il ressort de ces observations qu'il existe des différences anatomiques importantes entre les habitants de pays tropicaux comme l'Inde et ceux de pays froids. En Inde, les éléments périphériques du corps sont relativement plus développés, les extrémités plus longues, le tronc plus court et plus étroit, ce qui réduit le poids du corps (notamment celui du foie).

Ces différences tendent vraisemblablement à accroître la surface d'évaporation ou de rayonnement et à réduire la production de chaleur métabolique par une diminution relative de la masse cellulaire active, ce qui contribue à régulariser la température du corps malgré la chaleur et l'humidité du milieu tropical. Cette étude confirme que les « règles climatiques » définies par Bergmann et Allen sont applicables aux populations humaines de pays tropicaux comme l'Inde. Les observations de l'auteur sont d'ailleurs corroborées par une étude anthropométrique faite récemment par la Division de physiologie du Central Labour Institute, à Bombay, et comprenant 31 mensurations anthropométriques opérées sur 500 sujets de sexe masculin habitant la région occidentale (Bombay) de l'Inde.

DISCUSSION

G. Lambert. Ne pensez-vous pas qu'il soit difficile de comparer, du point de vue anthropologie, des groupes de populations vivant dans des conditions écologiques aussi différentes que celles des Indiens et des Américains?

R. N. Sen. The limitation of such a comparison was kept in mind. In view of the extreme paucity of data, this preliminary attempt was made and the available data were compared with those of Westerners to show the difference. Considering the differences in the habits among these groups of Indian subjects and the similarity of their anthropometric measurements, the effects of the climate cannot be ruled out. Or course, the effects of other factors should also be studied.

C. H. Wyndham. I do not feel that Dr. Sen can make any comparison in this way. He has isolated climate as the main determinant in the anthropometrical differences but there are many others, such as diet, exercise, etc., which might be much more important. How does he explain this?

R. N. Sen. It is likely that factors such as diet, exercise, etc., might have their effect, but it is interesting to note that though the climatic conditions of the two zones of India and the mean linear anthropometric measurements of the subjects are quite similar there are marked interindividual differences in the quality and quantity of the diet consumed and also in their occupations as students and workers. It would be interesting to see if factors such as diet and exercise would grossly influence the linear measurements. The difficulty of getting a long-term control over diet and working conditions to obtain their isolated genetic effect on the anthropometric measurements is obvious.

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SEN R.N, KAR M.R. (1978)

Circadian rhythms in some groups of Indians ~~work~~ working in shifts

JOURNAL OF HUMAN ERGOLOGY 7 65.79

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8 industrial worker (shift) | healthy and young as usual in SEN's studies.
6 sedentary

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typical SEN Balanced position.

„In order to get maximum efficiency from a biological machine without endangering its well-being, health and longivity, we must consider the ease and promptness of adaptibility of the different body systems of the workers to the rotating work schedules because round the clock activity will be a must in near future in industries for brighter economy and also it is going to be adopted in all other spheres of human functioning for better output, quantitatively as well as qualitatively.. With further study, it will possible to find out the important parameters which may be employed to pre-select the shift workers suitable for specific shifts or rotating shifts with maximum productivity ~~continuing~~ through maximum number of days with unaffected health." [is its political philosophy, economy or work physiology?]

The results would have been interesting in the 30ies

J. Human Ergol., 7: 65–79, 1978

CIRCADIAN RHYTHMS IN SOME GROUPS OF INDIANS WORKING IN SHIFTS

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The present study was undertaken in order to find out the effect of changes of shifts on different physiological responses in Indian industrial workers. Two groups, one of 8 workers from industries and another of 6 sedentary subjects used as control, acted as volunteers in this study. The first group worked in three different shift rotations: morning, afternoon and night. The second group worked in two shifts: day and night only. Different physiological responses, specially the pulse rate and oral temperature, were recorded hourly. The other physiological responses, such as frequency of micturition, gastro-intestinal disturbances, hours of sleep were also noted. Several days of consecutive work and recreational activities were considered in each subject. In the control group, the oral temperature rhythm did not change significantly with the change of shifts; so did the pulse rate rhythm. But this group had less sleep and higher frequency of micturition in the night shift routine than those during day shift. The typical industrial workers' oral temperature rhythm also did not change significantly with the shift changes, but their pulse rate rhythm changed slightly with shift change, possibly in an attempt to adapt. They generally slept well in all 3 shifts and had micturition equally frequent. However, there were individual variations with some peculiarities in both the groups.

The external and internal environments of the living organisms oscillate in different rhythms. The capacity of the living organisms to follow the external environmental rhythms and to oscillate in harmony with them enhances the survival potency of a species. Of so many types of rhythms, human beings are very much concerned with the circadian ones as these immensely influence and guide them (ASCHOFF *et al.*, 1967, 1974; COLIN *et al.*, 1968; FRAZIER *et al.*, 1968; HALBERG *et al.*, 1966; KLEIN *et al.*, 1970; OGATA *et al.*, 1962; OSTBERG *et al.*, 1973; SASAKI, 1964).

The relationship between internal 24-hour rhythms and external work sched-

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ules is important because performance and its allied matters are influenced when the internal rhythms, normally synchronised to the rhythms of society, experience a change of the external working condition. Such a change is imposed on persons who work in rotating shifts. These changing work schedules and their effects on body and mental functions need detailed investigation.

The present preliminary study was undertaken to see the effects of shift changes in industries on the different physiological and pshychophysiological responses of the Indian industrial workers with an aim to (1) find out the adaptability of each worker with respect to each of the physiological responses to different shift schedules, and (2) to find out the association, connection and relation among the different responses in the constantly rotating routines.

MATERIALS AND METHODS

The workers and the schedules of their work. In the present investigation, one group consisting of 8 healthy workers (age-group 22–30 years), with about

the whole 24-hour data of that particular subject was rejected. Additional monetary and sociopsychological incentives were given to the subjects for proper recording of the data, which were examined and verified from time to time by surprise on-the-spot visits.

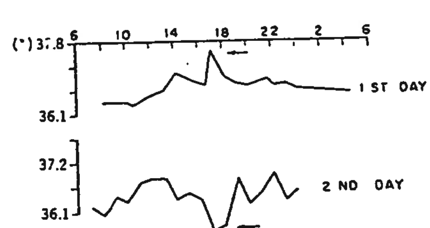
Variations of oral temperature and pulse rate during 24 hours were plotted for each individual subject as well as for the whole group. Mean difference between the maximum and minimum values of each response represents the amplitude of the parameter. The mean for each individual subject given in the tables were obtained during each particular shift from all the hourly values for all the days.

Using the least square approximation, best fitting lines were drawn on each of the 24-hour period for each subject in order to detect the trend of the rhythm. The students' *t*-test was performed on the mean value of each parameter to see if there was any significant difference between different shifts.

RESULTS AND DISCUSSION

Individualities of control subjects (*without any change of shifts*)

When the circadian graphs of individual subjects were plotted for consecutive days with the values of subjects living with normal or standard routine (*i.e.*, outdoor activities during office-hours at midday, and rest at night), as well as from subjects working in rotating shifts, it was observed that each individual exhibited some specific type of rhythm with some peculiarities so typical for that individual. The



ules is important because performance and its allied matters are influenced when the internal rhythms, normally synchronised to the rhythms of society, experience a change of the external working condition. Such a change is imposed on persons who work in rotating shifts. These changing work schedules and their effects on body and mental functions need detailed investigation.

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MATERIALS AND METHODS

The workers and the schedules of their work. In the present investigation, one group consisting of 8 healthy workers (age-group 22–30 years), with about 4 years of experience in the shift work, were taken from different factories with the same rotation of shifts from morning (A) to afternoon (B) to evening (C) for 8 hours a day, 6 days a week and one week for a shift. Shift "A", *i.e.*, the morning shift was from 0 hour to 14 hour, shift "B", *i.e.*, afternoon shift was from 14 hour to 22 hour, and shift "C", *i.e.*, night shift was from 22 hour to 06 hour. Another non-industrial group of 6 volunteers of similar age-group was also taken as control subjects who followed the routine of 2 shifts: day and night. They were engaged in sedentary work (reading, writing, sorting cards, household work, *etc.*) for 8 hours a day, 6 days a week and one week for each shift. They did not work in this change of two shifts earlier. This group of control subjects, non-habituated to shift changes, was taken to find out the differences of quality and amplitude of the impact of the change of living routine as compared to these of the persons havituated in shift work.

Physiological responses during shift work. The volunteers, both industrial and non-industrial sedentary (*i.e.*, control) were subjected to hourly measurement of oral temperature (with properly calibrated clinical mercury thermometers) and of pulse rates. The subjects did not take any hot or cold drinks or did not talk, and kept their mouth shut at least 15 minutes before the measurement of oral temperature. The thermometer was kept under the tongue at least for 5 minutes. The pulse rate was recorded hourly, after at least 5 minutes' rest during the off-hours and during work on the shop floor without interruption of activity. To avoid disturbance in the natural sleep, the oral temperature and pulse rate were not recorded during the periods of sleep unless the subject woke up spontaneously for some reason. The subjects took the measurements themselves after a thorough training in the technique. Some of the sample data were checked for a few days during the trial period as well as during the actual experimental periods to see if the data were being collected properly or not. In case of any discrepancy,

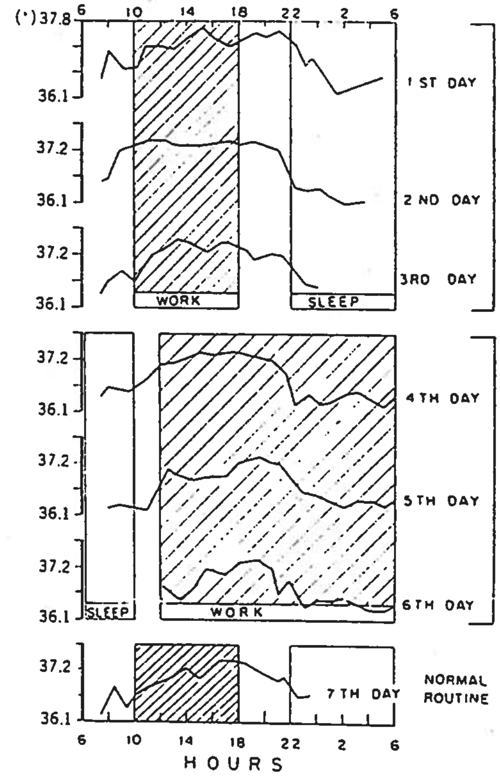

Fig. 2. Oral temperature rhythm of a subject (PP) in both normal and altered routines. Shaded areas indicate work periods and blank ones sleep periods.

sustenance and recurrence of a particular type of circadian rhythm was evident in case of a few individuals as can be seen in Fig. 1 which shows the hourly oral temperature values of one of the control subjects (GGR) for 5 consecutive 24-hour days with normal and standard routine (academic persuits in an institute during office-hours followed by sedentary recreational activities in the evening and sleep at night). This subject tended to repeat his circadian oral temperature pattern every alternate day, whereas in Fig. 2, the values of the hourly oral temperature of another control subject (PP) did not alter his previous basic circadian rhythm during normal routine even after 3 days of night work. Work of MEDDIS (1968) also revealed similar nature of fixity of the oral temperature rhythm in a control subject who followed a 48-hour routine (instead of 24-hour *i.e.*, circadian) and slept alternate nights and still maintained the circadian rhythm of body temperature. It has been reported that there was little or no physiological or psychological adaptation to the 48-hour routine, although it was harmless to follow the routine for 1–2 months. In another experiment COLQUHOUN *et al.* (1968) noted only a partial adaptation of the temperature rhythm to the night shift schedule even when the control subjects were tested for a period of as long as 12 consecutive days on each shift. MIYAZAKI *et al.* (1970) reported their experiment of daily shifting of living routine of control subjects with a progressive advance (up to a very limited extent of time only, of course) in the rising hour in the morning caused the morning rise of body temperature to commence earlier and but when the hour of rising was too early, it failed to bring any change then. KLEITMAN and JACKSON (1950) found that the less the deviation from the usual routine, the better was the adjustment of the body temperature curves to the new cycle.

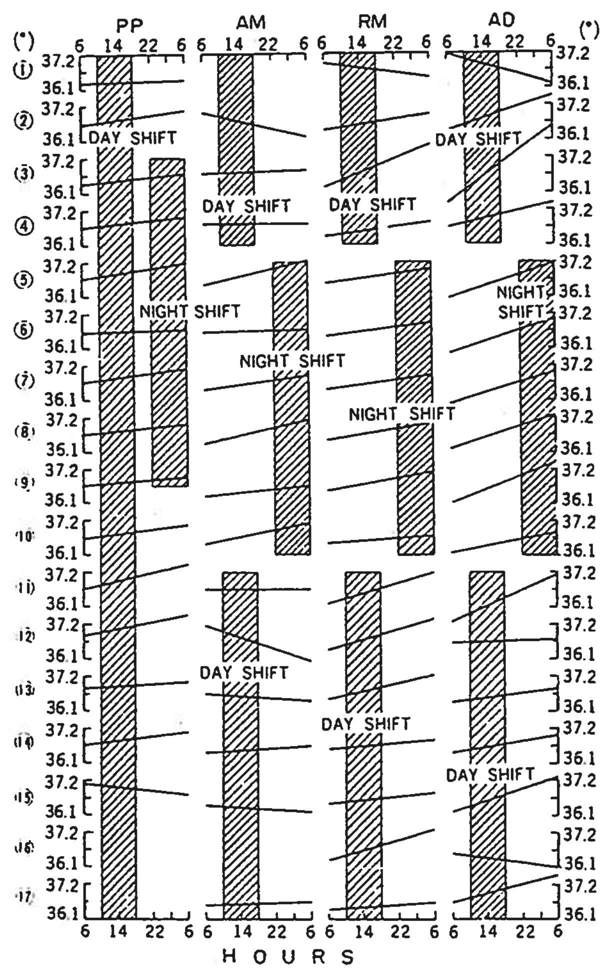

Fig. 3. Individual oral temperature rhythm in 4 subjects (PP, AM, RM, AD): Best fitting lines of each 24-hour-day curve. Figures within circles represent the serial number of consecutive days of experiment (subject PP observed night shift routine in addition to his fixed day shift routine).

Variation of oral temperature in the control group of subjects (simulation of shift work)

Figure 3 is the comparative presentation of the best fitting lines obtained by the least square method of the day-to-day oral temperature curves obtained from four subjects of the control group (PP, AM, RM, AD); Fig. 4 on the other hand is a cumulative graph and shows the hourly mean values of all the 6 control subjects for all the 6 consecutive days during the day shift routine as well as during the night shift routine. It is evident that when the control group of subjects (who are non-industrial and sedentary) went to the night shift from the day shift, the pattern of the rhythm of oral temperature did not change with the change of shift, although there was a change in the mean oral temperature (mean of 24 hours), as well as in the amplitude of oral temperature for each of the 6 subjects as given in Table 1. In the night shift the amplitude was little lower than those observed in the day shift similar to those observed by KAMIMURA *et al.* (1970). One of the reasons may be due to the inclusion of less number of readings available during the day time when the subjects were sleeping. However, this lowering of temperature may also be due to the lower metabolic rate during the night similar to the observation of LEKHAN (1972).

Variation of oral temperature in the group of industrial workers (typical shift work)

The hourly average values of oral temperature and pulse rate (with S.D.) of all the industrial workers for all the days in each of the three shifts are presented in Fig. 5.

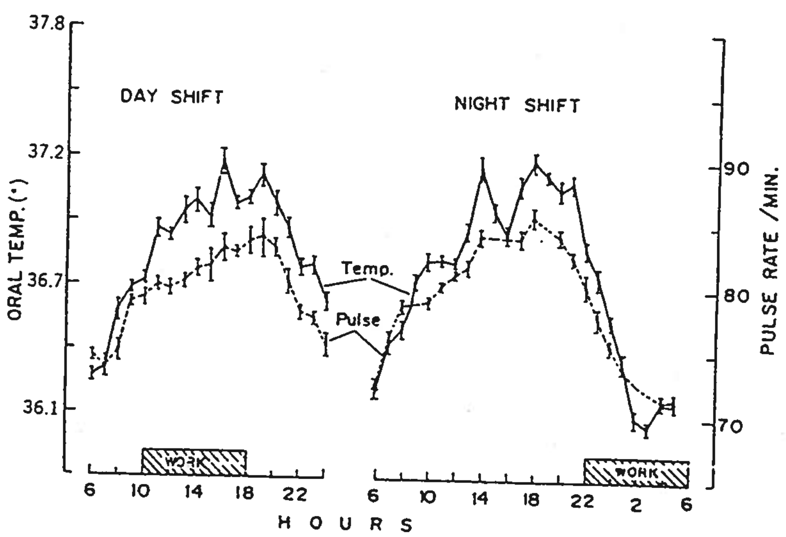

Fig. 4. Cumulative graph for oral temperature and pulse rate rhythm of control group of subjects ($N=6$) with common routines of shifts. Shaded portions indicate periods of work/activities in respective shift routine.

Table 1. Oral temperature (°) variations.

Industrial shift workers	Average 24-hour-mean oral temperature						Mean amplitude					
	Shift A		Shift B		Shift C		Shift A		Shift B		Shift C	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
SNDB ($D=8$)	37.15	±0.072	37.12*	±0.189	36.93*	±0.072	1.1	±0.394	1.23	±0.206	1.67	±0.478
BM ($D=10$)	37.02	±0.067	36.99*	±0.061	36.8*	±0.100	0.92	±0.167	0.91*	±0.206	0.57*	±0.072
MG ($D=10$)	36.96	±0.072	37.08*	±0.122	36.9	±0.072	0.91	±0.256	1.12	±0.517	1.08	±0.511
SM ($D=12$)	36.99	±0.072	37.03	±0.033	36.93	±0.080	0.93	±0.056	1.08	±0.094	1.11	±0.067
PS ($D=10$)	37.01	±0.067	37.12	±0.106	36.87	±0.044	1.01	±0.061	0.87	±0.144	0.57	±0.100
SP ($D=14$)	36.68	±0.072	37.17	±0.061	36.92	±0.106	0.81	±0.044	0.96	±0.061	0.79	±0.228
JG ($D=11$)	36.87	±0.083	37.03*	±0.078*	36.78	±0.067	0.81	±0.033	0.61	±0.106	0.56	±0.094
KB ($D=7$)	37.04	±0.061	37.03	±0.067	36.91	±0.044	0.91	±0.061	0.91	±0.044	0.62	±0.067

Control group	Day shift		Night shift		Day shift		Night shift	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
PP ($D=6$)	36.83	±0.222	36.71	±0.106	0.71	±0.233	0.65	±0.100
AM ($D=6$)	36.65	±0.144	36.59	±0.089	1.02	±0.261	1.28	±0.272
AD ($D=6$)	36.68*	±0.222	36.36*	±0.094	1.11*	±0.400	1.56*	±0.200
RM ($D=6$)	33.66	±0.089	36.62	±0.050	0.86	±0.378	0.96	±0.267
LM ($D=6$)	36.77	±0.106	36.67	±0.089	0.98	±0.283	1.04	±0.272
MK ($D=6$)	36.66	±0.172	36.82	±0.122	1.06	±0.239	1.11	±0.317

D, number of days of observation; A, morning shift; B, afternoon shift; C, night shift; SD, standard deviation.
* The values are significant below 5% level.

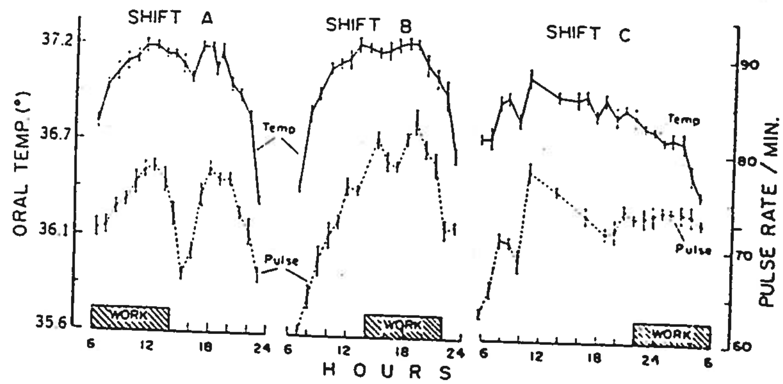

Fig. 5. Cumulative graph for oral temperature and pulse rate rhythms of a group of industrial workers ($N=8$) with common routines of shifts. Shaded portions indicate periods of work on the shop-floor.

A similar change as seen in the control group described above, occurred in the regular shift workers. Their circadian rhythm of oral temperature in the morning shift (shift A) was like that of the day shift of the control group. And on going to the shift B (afternoon shift), the rhythms of both oral temperature and pulse rate did not change significantly except a slight change in the position of the peak of the curve which had been shifted to a later period. On going to the night shift, the patterns remained essentially the same, except a slight lowering of both the mean values and the amplitudes.

To some extent a similar type of response was noted by KAMIMURA *et al.* (1970) where the diurnal rhythm of body (oral) temperature in workers on the morning shift showed a pattern similar to that of the men in an ordinary routine. In the present study, the working hour of the day shift of the control group nearly corresponded to the working hour of the men in ordinary routine of the above-mentioned study. In contrast to the present study, Kamimura observed that temperature rose at night shift (being highest at 7.00 hr.) compared to two other shifts. In the present study temperature was found to be on the decline in the night shift compared to two other shifts. Of course here is a point to note that the said night shift to Kamimura was a bit different in timing, being concluded at a later hour (7: 30 hr.) compared to the present study (where night shifts are being operated between 22: 00 hr. and 6: 00 hr). However, in another study, WATANABE (1968) noticed no sign of synchronisation of the temperature to the living and work schedule within a five-day rotation period, whereas according to TELEKY (1943) night work causes either a tendency to inversion or a true inversion of the temperature curve within a week for most people if there is a physical work to be done (factory work); but if the work is essentially mental or involves less physical work (as in the case of the control group of the present study) the tendency is less and the required time is longer.

VAN LOON (1963) attributes the reason for contradictory findings and opinions on temperature rhythm-work/rest cycle relationship to the relative infrequency of data collection; he points out that this infrequency leads to difficulty in recognising a change in the rhythm if and when it takes place. On the other hand, KLEITMAN (1963) was of the view that the failures to demonstrate inversion are probably due to the impatience of the investigators who expects results within a very short period; but actually in a situation where individual variations in resistances to phase-change are very wide, it is necessary to continue observations for a much longer period. It may be added that this period of observation, besides being longer, would moreover have to be separated into two distinct types for observations and interpretation: (a) Period "contaminated"—the experimental subject going back to holiday routine in off-days, and (b) Period uncontaminated (*i.e.*, the experimental subject continuing in any shift without "off-days"). Because, the point of "contamination" of the data collection period is a major cause of difference in results among observers and individual differences among subjects of a single observer. The data in the present study was therefore collected in uncontaminated condition. Different experimental subjects may take a different number of off-days at different dates in addition to the affair of 'off-day' at week-end. Even going to the single week-end off-day itself, when they resume the normal work/rest pattern, very probably resulting in reversion to normal temperature rhythm. However, we learn more from VAN LOON (1963) that the essential change in the rhythm after night work is the flattening of temperature curve rather than total inversion and one should not take a shift in phase as the primary criterion for deciding the question of adaption.

Mean oral temperature of 24 hours and the amplitude of temperature of each subject was lowest in the night shift (except in two subjects: SP and MG as given in Table 1). It was interesting that the subject (SNDB) whose mean oral temperature was lowest (36.93°) in the night shift, the difference between the means of the shifts A and C was statistically significant ($p<0.001$) and of the shifts B and C was ($p<0.005$) also significant, as revealed by students' t-test; whereas the mean amplitude of temperature was highest (1.667°: the p value for the t-test were not significant). This subject (SNDB) expressed his preference for the morning shift and had a strong dislike for the night shift. Another subject (JG), also had his minimum 24-hour mean temperature (36.78° and $p<0.001$ of t-test between C and A) in the night shift but the amplitude of his temperature also was the lowest in night shift and, interestingly, he expressed his preference for the night shift. A study on the comparative relations of mean oral temperature and its amplitude to the worker's suitability on a particular shift is in progress on a large group of industrial workers with different degrees of heaviness of job.

The rhythm of pulse rate

As shown in Figs. 4 and 5, the pulse curve had more or less pattern similar to the oral temperature curve althroughout except a few momentary changes due to short bursts of activities. With a change of shift, it also followed the oral temperature curve specially in the case of non-industrial shift-workers. Here also, like the temperature rhythm, the 24-hour mean pulse rate and the amplitude was generally lower in the night shifts than those in the day shifts as shown in Table 2. When the pulse rate rhythm of shift-workers was considered, it tended to fall more in the night shift similar to the observation of DALEVA *et al.* (1972). But the pulse rate rhythm as compared to the oral temperature rhythm was slightly dissociated towards the end of the night shift as shown in Fig. 5. It appears that pulse rate is more adaptable to the work schedule and its circadian rhythm is slightly less-rigid than the temperature rhythm. KLEITMAN *et al.* (1963) preferred to conclude that the diurnal heart rate curve is not a physiological rhythm like the diurnal oral temperature curve, but a simple periodicity, immediately coupled with the daily routine of living. However, it is interesting to note that the pulse rate followed the physical activity much more in industrial shift workers than in the non-industrial control group.

The subject (SNDB) who preferred the morning shift to the night shift, had the lowest amplitude of pulse rate in the morning and highest in the evening, and the subject (JG) who preferred the night shift, had his lowest amplitude in the night.

Hours of sleep

The total hours as well as the quality of sleep of the industrial shift-workers were not much different in the three shifts except a very slight diminution of sleep hours and satisfaction in sleep in the week of night shifts as shown in Table 3. But the total sleep hours for each 24 hours in the sedentary non-industrial control group, who got the same opportunity for sleeping freely on the dates of day-shifts and night shifts was much less in the days of night shifts than in the days of day shift of normal routine. Socially, the individual's opportunities were restricted from full participation in the social activities which are designed mostly for day time work, and the control subjects were not accustomed to shed off the anxieties for socially and psychologically-desynchronised and altered routines. Besides, the non-industrial sedentary control group was obviously disturbed in their improper sleeping environment in the day time when they followed night shift routines. Thus the difference in the sleep hours in the day and night shifts may be due to the non-indentical sleeping and social conditions in the two shifts. The importance of social cues were stressed by ASCHOFF *et al.* (1971) in their experiment and they found it to be of primary importance for retention of the circadian rhythms (preventing inversion). GIEDKE *et al.* (1974) also took the social zeitgeber as sufficient for the maintenance of human circadian rhythms.

Frequency of micturition

The frequency of micturition of the individual industrial shift workers were

Table 2. Pulse rate variations.

Industrial shift workers	Average 24-hour-mean pulse rate						Mean amplitude					
	Shift A		Shift B		Shift C		Shift A		Shift B		Shift C	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
SNDB (D=8)	80.3	± 9.8	76.5	±10.3	74.3	± 9.4	25.3	±3.54	26.4	±4.11	30.1	±2.98
BM (D=10)	72.6	±11.5	78.2	±12.2	73.5	±11.9	24.2	±4.12	27.2	±3.04	25.1	±2.14
MG (D=10)	73.1	±10.6	76.4	± 9.1	70.6	± 8.5	22.1	±3.67	24.2	±2.89	29.4	±3.01
SM (D=12)	77.5	± 8.1	79.2	±12.5	74.1	±10.2	19.3	±2.74	16.2	±3.13	24.5	±3.77
PS (D=10)	78.3	±10.4	82.1	±12.1	75.2	± 8.7	20.6	±3.71	22.0	±2.67	22.7	±4.18
SP (D=14)	74.2	± 9.7	78.7	±10.4	70.4	±12.9	24.4	±3.10	22.1	±2.09	25.6	±3.98
JG (D=11)	75.4	±11.3	80.3	± 8.7	72.7	±11.6	20.7	±2.12	21.4	±3.37	15.1	±2.19
KB (D=7)	79.7	± 8.6	80.4	±11.8	71.6	± 9.8	26.6	±3.47	23.4	±4.16	28.9	±4.41

Control group	Day shift		Night shift		Day shift		Night shift	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
PP (D=6)	86.46	±3.19	84.0	±1.77	19.3	±6.91	21.7	±5.85
AM (D=6)	82.2	±1.47	81.2	±1.31	22.3	±8.93	21.7	±5.09
AD (D=6)	85.5*	±9.44	78.8*	±1.82	39.9	±13.13	48.9	±7.99
RM (D=6)	83.1*	±2.43	75.9*	±1.61	28.1*	±6.17	37.2*	±3.99
LM (D=6)	76.2	±3.2	72.1	±3.4	19.4	±5.12	17.3	±4.61
MK (D=6)	79.3	±2.9	76.7	±2.8	20.2	±7.26	18.1	±6.34

D, number of days of observation; A, morning shift; B, afternoon shift; C, night shift; SD, standard deviation.
* The values are significant below 5% level.

Table 3. Mean hours of sleep in each 24-hours.

Industrial shift workers	Shift A		Shift B		Shift C	
	Mean	SD	Mean	SD	Mean	SD
SNDB (D=8)	7.13	±3.1	7.47	±3.7	5.63	±3.9
BM (D=10)	7.62	±4.1	7.93	±2.7	7.55	±2.9
MG (D=10)	8.04	±3.3	8.22	±3.2	7.81	±4.2
SM (D=12)	7.60	±3.4	7.58	±4.3	7.17	±3.4
PS (D=10)	6.23	±2.8	6.45	±3.6	5.64	±3.8
SP (D=14)	5.93	±3.3	6.02	±3.5	5.14	±4.3
JG (D=11)	6.45	±3.1	6.81	±4.0	5.91	±3.5
KB (D=7)	6.71	±2.7	7.03	±3.2	6.28	±3.6

Control group	Day shift		Night shift	
	Mean	SD	Mean	SD
PP (D=6)	9.67*	±2.1	4.17*	±2.4
AM (D=6)	6.97*	±2.2	2.86*	±2.6
AD (D=6)	9.34*	±1.9	5.43*	±2.0
RM (D=6)	8.12*	±2.4	3.18*	±1.8
LM (D=6)	7.81	±2.7	4.45	±2.6
MK (D=6)	8.59*	±2.1	4.24*	±2.2

D, number of days of observation; A, morning shift; B, afternoon shift; C, night shift; SD, standard deviation.

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more or less the same (Table 4) in three rotating shifts, although it was reported by Froberg (1972) that diuresis happened to be lowest in the night shift among the three shifts. In the non-industrial control group, the micturition frequency was higher during night shifts in comparison to that during the day shifts.

Adaptation to change to shift

Sleep hours and micturition frequency. It is known that there are individual variations among the industrial workers in the time taken for adaptation to different shifts, specially to the night shifts; this adaptation or non-adaptation or poor-adaptation in this study were reflected mainly through the duration of sleep and the micturition-frequency. A few subjects (JG, BM) took only two consecutive days to have a good sleep on going to the night shift from the afternoon shift, and others took as long as 5 to 6 consecutive days for a good sleep. There are reports (Belova *et al.*, 1974) that the restoration of the previous rhythms of sleep/wakefulness was seen after two days of rest, but from this study no generalisation could be made as it requires fully controlled environment (such as sleeping chambers) identically same for all the subjects, which were not possible in this study.

Gastro-intestinal disturbances. The gastro-intestinal disturbances in the form of indigestion, acidity, constipation, *etc.* appeared in two of the industrial shift-

Table 4. Mean micturition frequency in each 24-hours.

Industrial shift workers	Shift A		Shift B		Shift C	
	Mean	SD	Mean	SD	Mean	SD
SNDB ($D=8$)	4.9*	±0.91	5.4*	±1.02	7.0	±0.96
BM ($D=10$)	6.1	±0.82	5.9	±0.72	5.3	±0.74
MG ($D=10$)	6.5	±0.76	6.0*	±0.65	5.1*	±0.81
SM ($D=12$)	8.3	±1.12	8.4	±0.84	7.9	±0.77
PS ($D=10$)	5.7	±0.81	6.2	±0.72	6.3	±0.67
SP ($D=14$)	7.1	±0.79	6.7	±0.96	6.6	±0.80
JG ($D=11$)	6.9	±0.83	6.5*	±0.78	5.2*	±0.59
KB ($D=7$)	6.4	±0.92	7.0	±1.51	6.7	±0.68
Control group	**Day shift**		**Night shift**			
	Mean	SD	Mean	SD		
PP ($D=6$)	5.2*	±1.55	7.8*	±1.5		
AM ($D=6$)	7.8*	±1.4	10.7*	±1.3		
AD ($D=6$)	4.5	±1.6	6.3	±1.0		
RM ($D=6$)	5.2*	±1.2	7.2*	±1.4		
LM ($D=6$)	6.5*	±1.1	9.3*	±1.7		
MK ($D=6$)	5.7*	±1.5	8.2*	±1.6		

D, number of days of observations; A, morning shift; B, afternoon shift; C, night shift; SD, standard deviation.

* The values significant below 5% level.

workers (SNDB, PS), but not in other control subjects; some of the control subjects complained about the difficulty in defecation after a change of shift. There are reports by the previous workers (BARHAD *et al.*, 1969) who maintain the view that intolerance to shift rotation is manifested by gastric disturbances. TAKAGI (1972) reported that a large number of shift workers suffer from digestive disorders. Among the two subjects mentioned above, SNDB who preferred the morning shift and disliked the night shift, frequently used to feel uneasy for some sort of indigestion and difficulties in defecation, from the very second day of going to the night shift till the second or third day of the next shift change (*i.e.*, morning shift).

CONCLUSION

Thus it seems that the circadian rhythms of the different body systems have some bearing upon health, on which the efficiency of work depends, and in turn is modified by (a) the work load (SAUTKIN *et al.*, 1974), and (b) the habit or training of work in changing schedules. In order to get maximum efficiency from a biological machine without endangering its well-being, health and longivity, we must consider the ease and promptness of adaptability of the different body systems of the workers to the rotating work schedules, because round the clock activity will be a must in near future in industries for brighter economy and also it is going to be adopted in all other spheres of human functioning for better output, quantitatively as well as qualitatively.

With further study, it will be possible to find out the important parameters which may be employed to pre-select the shift workers suitable for specific shifts or rotating shifts with maximum productivity continuing through maximum number of days with unaffected health.

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SARIT KUMAR
MITRA
Avec un Chêne

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Coming from such a brilliant center M. Sri Samit Kumar Mitra thesis has to be considered with rather severe requirements. Even with such requirements, his thesis is quite satisfactory.

Both the scientific frame and the social demands are clearly expressed in the form of set of questions presented at the beginning of each chapter and answered at the end in a very demonstrative way. The methods are classical, justified and well related to the theoretical frame.

The anthor explains clearly how numerous are the workers who are engaged in the strenuous work found in brick fields. This consideration underlines the necessity of studying specially this group of workers who have not yet been subjects of a scientific evaluation.

It seems that the sample studied coming from 3 brick-fields among the 4000 found in Eastern India (West Bengal) is representative of the whode population of brick fields workers though it is of course very difficult or impossible to give a full demonstration. In fact their height (# 163 cm), their weight (20-29 years old # 50 kg, 30-39 years old 56 kg) and their $V0_2$ max (2,20 liters minute -1) and $V0_2$ max per Kg (45 ml Kg $^{-1}$ minute $^{-1}$ for younger men, 40 ml Kg $^{-1}$ minute $^{-1}$ for elder men) are rather typical of rural indian industrial workers selected among the

farmers by the employers. The author has himself reinforced this selection in choosing "subjects with good physique as well as apparent physical fitness - willing to cooperate and having at least two years experience in the brick industry" (p. 61). We may also remark that the mean age of the sample is 30 Y with a group of young workers (mean age 25 Y) and "old" workers (mean age 36 Y) No worker older than 40 Y was considered.

We have no information about the nutrition status of these workers or their financial ressources (salary, extended family) so we cannot know really if their important training has resulted in a full development of their physical capacities. We may consider that their characteristics are between those of villagers (Nag, 1981) and those of industrial workers (Sen and Sarkar, 1979).

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This result linked to the fact that no worker is aged more than 40 Y. May indicate that work in brick fields may be so strenuous that it could affect the long term health of workers. But we have not facts about the oxygen consumption during work. These data are very difficult to obtain and very rare. But we can learn in the thesis what is the global physiological load with many measurement of heart rate. This measure has the great advantage of integrating heat load. The author brings very convincing evidences of the influence of thermal environment showing striking difference between seasons and hours of the day. If the influence of heat specially on elder workers is quite classical, very convincing demonstrations of

climatic differences are rare in the litterature. The results obtained by the author among brick field workers are very convincing and of utmost interest. Some results are really appaling : means of 136bp for both groups during the fifth working period at the end of the morning during summer. In the 2 last periods of the morning and the 3 last periods of the afternoon mean pulse rate is superior to 130 bpm for younger puddlers !

These data raise the question of the classification of work from the viewpoint of heaviness. It is difficult to avoid a critical reflexion about the validity of Christensen'scale in these special population activities and climate. Anyway "it is more or less universally admitted that heart beat rate should not exceed 110 beats/minute for long periods during the work day. During more intensive work periods 130 beats/minute should not be exceeded" (Wisner A., 1989, International Journal of Industrial Ergonomics, 4, 117-138).

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I repeat my high appreciation of the thesis of Mr Samit Kumar Mitra. Reading his book has been extremly interesting and stimulating for me and I hope that the University of Calcultta will award M. Samit Kumar Mitra with Ph. D. with the highest possible appreciation.

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The correlation between bothy height and Forced Vital Capacity (F.V.C.) is well established and the regression equation very useful.

The author gives a new demonstration of the influence of age on working capacity. It could be wise to change a little fig. 1 (p. 107) where we see the measured points in a situation not corresponding exactly to the written presentation of the results. Either these points correspond to the two means related to age groups and it would be better to see the left point at 44,60 (ml kg $^{-1}$ minute $^{-1}$ and 24,4 Y and the right point at 40,21 ml Kg $^{-1}$ minute $^{-1}$ and 35,57 Y or if the regression line has been calculated from all the data the 2 points are not necessary. This is a detail on which I may be wrong. Another remark may be related to the fact that the author has observed a rather big difference in $V0_2$ between 2 groups which mean age differ only by 10 years. This difference is more important than what as been found by Nag and coll. (1980) and Nag (1981).

This result linked to the fact that no worker is aged more than 40 Y. May indicate that work in brick fields may be so strenuous that it could affect the long term health of workers. But we have not facts about the oxygen consumption during work. These data are very difficult to obtain and very rare. But we can learn in the thesis what is the global physiological load with many measurement of heart rate. This measure has the great advantage of integrating heat load. The author brings very convincing evidences of the influence of thermal environment showing striking difference between seasons and hours of the day. If the influence of heat specially on elder workers is quite classical, very convincing demonstrations of

climatic differences are rare in the litterature. The results obtained by the author among brick field workers are very convincing and of utmost interest. Some results are really appaling : means of 136bp for both groups during the fifth working period at the end of the morning during summer. In the 2 last periods of the morning and the 3 last periods of the afternoon mean pulse rate is superior to 130 bpm for younger puddlers !

These data raise the question of the classification of work from the viewpoint of heaviness. It is difficult to avoid a critical reflexion about the validity of Christensen'scale in these special population activities and climate. Anyway "it is more or less universally admitted that heart beat rate should not exceed 110 beats/minute for long periods during the work day. During more intensive work periods 130 beats/minute should not be exceeded" (Wisner A., 1989, International Journal of Industrial Ergonomics, 4, 117-138).

The author has produced very interesting recovery heart rate curves. We may remark that in summer these curves are totally or partially above the safe limits (1st minute 110bpm, 2 nd 100, 3 rd 90) proposed by Brouha even for the younger green brick makers or the stackers (3rd minute).

As an ergonomist, I am always interested by the practical recommandations that may be issued after a field research. To give precise examples, I would like to refer to L. Brouha book "Physiology in industry" (1967) quoted quite rightly a few times by the author in his thesis. Brouha suggest a few directions for solutions in the case of workers overloaded by physical work and heat : breaks taken in places relatively protected from heat sources (sun), limited duration of work, hats, baths (in the neighbouring canal), availability of abondant cool, good taste drinking water. I dont know how far for these solutions are realistie in the case of West. India brick fields workers, considering economical and cultural dimensions.

I repeat my high appreciation of the thesis of Mr Samit Kumar Mitra. Reading his book has been extremly interesting and stimulating for me and I hope that the University of Calcultta will award M. Samit Kumar Mitra with Ph. D. with the highest possible appreciation.

A. Wisner, professor emeritus

ØA FTU ΘR

DAFTUAR

Notes by WISNER
June 86

~~Legibil~~

(1) JHA S.S., DAFTUAR C.N. (1981) Legibility of type faces
JOURNAL OF PSYCHOLOGICAL RESEARCHES 25 2 108.110

~~[illegible]~~
no interest : old experimental ψ

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(2) CHATTERJEE A., DAFTUAR C.N (1966) Application of CORBUSIER'S HUMAN SCALE TO THE LAYOUT OF WORK SPACE FOR TYPWRITING JOURNAL OF ENGINEERING PSYCHOLOGY 5 2 54.62

Bad classical study :
typing performance (motivation??)
philosophical basis MODULOR of LE CORBUSIER

---

(3) DAFTUAR C.N (1977) Engineering psychology in cross cultural settings in ~~[illegible]~~ PORTINGA Y.H. Basic problems in cross cultural psychology SWETS and ZEITLINGER pub. AMSTERDAM

Very good paper

- 3.000 different languages are spoken in the world
- Spoken communication

The intelligence test VNART (Verbal, numerical, and abstract reasoning test) is in HINDI. It was translated to english for administration to 40 thai students. The test items were read out to them and they had to write the answers on the answer sheets. As I was myself administering the test but after covering the test was given [illegible] the responsibility of conducting the test was given to a Thai student. It was soon realized that after the Thai student has taken over, ~~that~~ the Thai subjects started performing better. The difference was highly significant ...... The experiment was repeated with Indians and gave the same result. This confirmed that the difference of pronunciation caused the difference in performance of the groups of subjects.

RUFFEL SMITH 1968.1978 spoke of that

WRITTEN COMMUNICATION - CONTENT PROBLEMS

Many languages have surprising paucity of technical terms. For example, several Indian languages are rich in content dealing with literature, history, philosophy and the arts but they are deficient in technical vocabulary. As a result, translators translate technical terms into Hindi or in some other Indian language have to use several stratagems to overcome the lack of proper words.... In India, the Central commission for scientific and technical terminology has so far designed and published half a million hindi equivalents of technical terms relating to natural and social sciences and humanities including professional subjects --

VIGILANCE JHA (1978) as observed that sleep deprivation had a deteriorating effect on performance of all subjects. The effect of sleep-deprivation on the Indian sample seemed to be more pronounced than on western subjects.... One possible explanation of this difference is that Indian students belonging to middle class in our sample) as compared to Western students suffer from vitamin deficiencies [I think that it is a bad explanation, I believe more in the idea that indian students have different sleep habits and that they are usually lacking of sleep] Several of our student subjects founded it extremly difficult to sustain even 24 hours of sleep deprivation (JHA 1976) .....

LEGIBILITY In my earlier experiments (DAFTUAR 1975) I worked with Bengali speaking students who also knew both the DEVANAGARI and the ROMAN alphabet. letters and digits of different sizes (8, 10, 12 and 14 points) were presented tachistoscopically presented to our subjects. The results indicated that the roman alphabet was significantly more legible than either DEVANAGARI and BENGALI. This is very interesting because ENGLISH was not my subjects' mother tongue ---- Arabic numerals and roman alphabet are simpler in structure than either DEVANAGARI or BENGALI .... Thai subjects obtained higher legibility score for numerals and lower for letters than Indian subjects [in what language?] ---

NEW TECHNOLOGY The available research data suggest that human beings are capable of adapting to highly technological society and that they can learn to operate and maintain highly sophisticated equipments. Psychological capacity to absorb technical training is not limited by race or ethnic group [he gives a very bad example : people resisting computers to avoid employment loss]

ATTITUDES TOWARD WORK AND PROFESSION

In some parts of the earth, there are strong biases against castes or occupations associated with "dirty hands" These attitudes are often reflected in lower average pay scales of people in such occupations. SINAÏKO (1975) observed "One reason for the scarcity of professional engineers among educated vietnamese is that engineering is considered a low status occupation". His observation was further generalized by CHAPANIS (1974) to cover "many Asian countries" My studies confirm SINAÏKO's observation but tend to negate CHAPANIS generalization [the observations are good but CHAPANIS was not in a position in 1974 to generalize the SINAÏKO remarks of 1975]

DAFTUAR compares opinions of THAÏ and INDIAN students on 16 diverse professions. They agree for some professions : University teacher is high (T:1, I3), Doctor (T:2, I1), College teacher (T:3, I 2), school teacher (T4 I4). Skilled labour is low (T 16, I 14) Manual labour (T 14, I 16) Clerk private (T 12, I 15). ~~Nursing (T 15, I 11)~~

But there are big differences: Business (T 5, I 10)

Agriculture (T- 13, I: 7) <u>Engineering</u> (T. 8, I 5) Executive (private) (T: 9, I 13). ~~In practice~~ Nursing (T15, I ~~31~~)
In practice Thai like more Business and Executive Business than Indians but less Agriculture, Engineering and Nursing.

The respectability of a profession and people's attitude toward toward it are not necessarily similar in different Asian countries or that few generalizations can be made on this score. Much depends upon the cultural heritage and the level of technological advancement in a particular country (or part of a country) --

In traditional India, a job is generally regarded as a family responsibility to such an extent that its performance is ~~to~~ shared by all the members of ~~the~~ a family... FRASER (1966) states that the failure of a weavers' cooperative started at BARAPALI VILLAGE SERVICE was due in part to the fact that the project technician, interested only ~~by~~ in selecting the best workers had drawn weavers from different caste groups that could not by tradition work together. ---

Another striking feature of many non-Westerners, including Indians is that they appear to have little regard for preventive maintenance. Machines are used until they break down. So in these countries, preventive maintenance needs much more emphasis in training for both operators and managers

This fact has serious implications for selection of equipment to be transferred from western countries. It may be better to accept somewhat lower performance in a system if maintenance demands can thereby be greatly reduced.

Dart (1972) made some anthropological studies of the Nepalese He observed :„ the villagers use no other kind of map : they do not use drawings in constructing a building or a piece of furniture, in fact they hardly use drawing or spatial representation at all and lack of spatial models as very natural. DART's observation is, at least to some extent, correct and is perhaps to that extent applicable to indian villages also. These villagers do not use any diagram or map but when they are asked to explain their proposed buildings or furniture they take help of a sort of informal diagrams, signs and gestures. They are perhaps capable, and may be trained to use drawings but customarily they ~~dot~~ do not use such diagrams.

ROAD SIGNS

43 undergraduate students of DAFTUAR having no driving experience

correct interpretation of indian road signs 0 → 75,5 %

mean : 40 %

One sign was not understood by any subjects. and no single traffic sign was correctly understood by all the subjects. Some road signs were even found to convey meaning to those actually intended (DAFTUAR 1975)

In fact very few accidents are in INDIA known to be related to misinterpretation of road signs. [They are just not considered for they are related to foreign frame of reference]

— — — — — — — — — —

Some underdeveloped countries have the material requisites, human potentialities and willingness to make economic progress but they suffer from mismanagement of their resources. Given proper opportunities and incentives most of these countries have the potentialities of being „achieving societies". This point of view may be a good starting point for human factors specialists in developing countries [Typical of line but so vague assertions that are so common of in the subject]

in fact PEPELASIS A., MEARS L., ADELMAN I (1961) Economic development analysis and case studies ~~HARPER and ROW~~ NEW YORK

---

(4) DAFTUAR C.N 1.958

A study of eye and hand-reach angle as a function of different body dimensions in typewriting job JOURNAL OF INDIAN ACADEMY OF APPLIED PSYCHOLOGY 3 2 40.46

Same philosophical and unuseful viewpoint as in paper (2)

(5) DAFTUAR C.N. (1977) Legibility of five digit arabic and DEVANAGARI numerals as a function of their sizes The journal of general Psychology 97 139-144

see list N: 3 Arabic ~~...~~ numerals are more legible

(6) DAFTUAR C.N., SINI J.K (1972) Sleep deprivation and human performance PSYCHOLOGIA, An international journal of ~~psy~~ psychology in the Orient ~~#~~ 15 2 122-126

No interest. Old fashion acute experiments (reaction time) in ~~the~~ relation with artificial sleep deprivation

7) DAFTUAR C.N. (1978-79) Occupational choice of indian and Thai students BEHAVIOROMETRIC 89 122 23-27

see report 3: Thai and indian students differ

(8) DAFTUAR C.N. 1969 Optimizing system and machine design following Human Scale of Proportion MANAS 16 1

[It is the post graduate thesis ~~....~~ work of the author]

Always LE CORBUSIER and the Golden Number

(9) DAFTUAR C.N. 1971 Some psychophysical problems for building designers: a human engineering point of view. PSYCHOLOGY 46 2 163-17 INDIAN JOURNAL OF

Old fashion but correct views in ergonomics in building design.

10

DAFTUAR C.N. 1971

Human factors research in INDIA HUMAN FACTORS 13 4 345-353

Research in the area of human factors engineering like the general growth in industrial psychological research has started gaining momentum in recent years ......

The Ergonomics Research of Society of INDIA has now ~~been~~ been formed .... A few noteworthy centers for human factors research are the Defence Science Laboratory, psychology directorate Ministry of Defence Air Headquarters; the psychotechnical cell, Ministry of Railways; The psychotechnological research laboratory, Indian institute of Technology KHARAGPUR, and the center established by the Author at GAYA-COLLEGE, and

The Central Labour ~~[illegible]~~ Institute BOMBAY.

Very banal studies of this period & 38 references

except ~~7~~ one:

SARAN C., OJHA T.P. (1967) Hand operated grain harvester - an aid to small scale mechanization AGRICULTURAL ENGINEERING 48 9 502-503

It is not a good paper

In fact " adapted technology

---

(11) DAFTUAR C.N. (1975) The role of human factors engineering in underdeveloped countries with special reference to India in CHAPANIS A. Ethnic variables in Human Factors Engineering THE JOHN HOPKINS PRESS pub BALTIMORE

Among 31 references, all from developing countries are indian (17) and 6 are from DAFTUAR!!

[Funny ~~ref~~ references from abroad] „ Mc CLELLAND *
1961 has suggested:

- the gradual substitution of such conflicting values as inner-directedness" or „caste" with „other directedness" and „market "morality"
- The ~~st~~ substitution of father figure dominance by figures of independent choice and action.
- The introduction of ideological reforms to unify other directedness, market morality and demand father-dominance
- The gradual introduction of educational programs with both short and long term benefits in the basic skill and knowledge requirements of a technological society.
- The reorganization of fantasy life to conform with a new cultural milieu
- the more efficient use of existing need achievement resources

---

*Mc CLELLAND ~~[illegible]~~ D.C. (1961) The achieving society
VAN NOSTRAND PRINCETON N.J.

But excellent consideration from Indian authors well summarized: DATTA 1961 in PAPELASIS's Book

The family and the castes

Agriculture DAFTUAR

Housing and architecture

Clothing

House-hold utensils.

Posture DAFTUAR C.N., BHAN V. M. 1966 . Postural efficiency with reference to paddy workers . Unpublished report

- Concept of efficiency McCLELLAND and WINER — DAFTUAR 1969

- Anticipating innovation [illegible] ++
- Automation strike against automation

PART 2 Some studies of visual displays (p 97 [illegible])

INDIAN ROAD SIGNS : see this summary p 6_7

LEGIBILITY OF ALPHABETS :

India has several regional languages, hundreds of dialects and many scripts

RIOTS against HINDI

Numerals — the best DEVANAGARI and ARAB; ~~the worst~~ worst ROMAN

Alphabets — the best ROMAN; the ~~worst~~ DEVANAGARI and BENGALI

[illegible]

PART 3 HUMAN FACTORS

FORESTRY WORKERS

A truly cross cultural field study was conducted under the cooperation of the Institute of ~~Work~~ Physiology (STOCKHOLM) and the forest research Institute (DEHRADUN) *

HANSSON J.E., LINDHOLM A., BIRATH H. (1966) Men and tools in indian logging operations : a pilot study in Ergonomics Report 29 ROYAL COLLEGE OF FORESTRY, DEPARTMENT OF OCCUPATIONAL EFFICIENCY

	SWEDS	INDIANS
WEIGHT	72 Kg	46–51 Kg (64–70%)
HEIGHT		−11–13 cm
$\dot{V}O_{2max}$ /Kg	=	
$\dot{V}O_{max}$ l/min		57–67%

The ~~in~~ indian system of felling by saw, lopping standing trees, turning logs and loading timber, impose heavy ~~w~~ work load on the back muscles and hence unnecessary risks of injury.

— — — —

A swedish axe the SATERPILEN and local indian axes were tested in barking, lopping, and undercutting. The swedish type of axe was better than the indian axe in undercutting and lopping but for barking the indian axe ~~proved~~ proved to be better .... The swedish axe had too small a back in proportion to the power developed and a bent shaft is unsuitable if the back as well as the edge of the axe is to be used

— — —

INDIAN WORKING POSTURES

[I am not convinced by this demonstration of the "good" ~~a~~ squatting posture]

– a manually operated harvester (SARAN and OHJA 1967)

[see page 8 of this summary]

The redesign of this harvester utilizes human power more efficiently. The human energy requirements are well within the limits of the average indian farmer, while the working speed and the height of the handle match his physical characteristics.

– a kitchen stove for indian homes. (used while squatting)

– a kitchen adapted to the indian style of life (a personal idea of a researcher for his own home kitchen.

JOURNAL OF PSYCHOLOGICAL RESEARCHES 1981, VOL 25, (2) PP. 108-110

Research Note:

Legibility of Type Faces

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Department of Humanities & Social Sciences, IIT Kharagpur

M. S. University, Baroda

Man's function in many man-machine system is that of a decision making and activating link between displays and controls. In these capacities his performance is in part dependent upon the rapid and accurate reception of information from the displays in the system. It is important, therefore, that the letters, words, numerals and symbols used, in visual displays be maximally legible. Precisely for this reason, legibility of Alphanumeric symbols continue to be the subject of interest. But the preferential study of the type faces from the legibility viewpoint is surprisingly few. Burt (1955) has studied the influence of type-face, boldness, size, interlinear spacing, length of line, and width of margin on legibility both with children and adults. His study revealed that the old style Antique appeared most appropriate for children under 12, and Imprint, Plantin, or Times New Roman for those over 12 years. She questions regarding several other type faces are yet to be answered. Particularly, in Indian context such research efforts are highly needed as a few such attempts have been made in past (Daftur, 1975, 1977a, 1977b).

The present study aims at making a preferential study of three type faces-Cheltenham, Sanserif and Roman-with two sizes for each (10- and 12 point) and in both the cases.

METHOD

Subjects: 50 undergraduates belonging to Gaya College, Gaya, acted as subjects. The mean age of the subjects was 18 years ranging from 16 to 21 years.

Apparatus and Test Materials

Stimuli consisted of nonsense syllables printed in three type faces-Cheltenham, Sanserif and and Roman-with two sizes for each (10- and 12-points) and in both the cases (upper and lower). Altogether 60 stimuli were used (5 stimuli × 3 type faces × 2 cases × 2 point sizes). Printing was done on white cards in black ink. Condensed form of type face was used for all. Stimuli were presented through a tachistoscope. The experiment was conducted in laboratory setting during day time.

Experimental Procedure

The viewing distance of 30" measured from cornea was kept constant with the help of a chin rest. The aparature exposure timing was fixed for 1/15 of a second.

Subjects were given complete instructions about the procedure used and some practice trials were given. Stimuli for practice trials were related to all veriety of test-stimuli.

The printed cards were arranged in random order, 60 different orders being used. Subjects were asked to pronounce the letters they saw and the responses were noted. One score was given for entirely correct reproduction of all the five letters and zero for incorrect. Rest of five minutes was allowed after

Manuscript received on March 16, 1981.

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Table
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12
10
*
13

the completion of 30 trials. The entire session lasted for about 30 minutes.

RESULTS

Table : 1 indicated that the mean legibility scores of 12 point Roman in upper case was superior to both Cheltenham had the highest mean score and Roman was better than sanserif. In 10 point size Cheltanham enjoyed the highest legibility. Particularly it proved markedly superior to Sanserif, as t - values in both the cases (t - 2.50 L .05; t = 3.52 L .05) were significant.

A comparative assessment of lower-, and upper cases revealed that the upper case was more legible in all the situations. In some cases (for example, 12-point Roman and 10-point Sanserif) differences were significant ($t = 2.75 < .05$; $t = 2.26, < .05$).

TABLE 1

Mean and t-Values of different type faces

12 point	Type Faces	Mean	Type Faces	Mean	t-values
Upper Case	Cheltanham	.93	Roman	1.36	.53
	Cheltanham	.93	Sanserif	1.00	.30
	Roman	1.36	Sanserif	1.00	1.60
Lower Case	Cheltanham	.90	Roman	.70	1.05
	Cheltanham	.90	Sanserif	.63	1.42
	Roman	.70	Sanserif	.63	0.38
10point					
Upper Case	Cheltanham	1.70	Roman	1.16	1.50
	Cheltanham	1.70	Sanserif	0.93	2.50*
	Roman	1.16	Sanserif	0.93	0.82
Lower Case	Cheltanham	1.10	Roman	0.73	1.85
	Cheltanham	1.10	Sanserif	0.50	3.52**
	Roman	0.73	Sanserif	0.50	1.09

* Significant at .05 level of Confidence.
** Significant at .01 level of Confidence.

TABLE 2

Mean and t-values of upper and lower cases of different type faces

	Type Faccs	Mean Upper	: Lower	t-values
12 point	Cheltanham	.93	.90	.14
	Roman	1.36	.70	2.75
	Sanserif	1.00	.63	1.70*
10 point	Cheltanham	1.70	1.10	2.01
	Roman	1.16	.73	1.59
	Sanserif	0.93	0.50	2.26*

*Significant at .05 level of Confidence.

TABLE 3

Mean and t-values of 12 and 10 point sizes of various type faces

Type Faces	Mean 12 point	: 10 point	t-values
Cheltanham Upper Case	.93	1.70	2.45*
Roman Upper Case	1.36	1.16	0.62
Sanserif Upper Case	1.00	0.93	0.31
Cheltanham Lower Case	0.90	1.10	1.05
Roman Lower Case	0.70	0.73	0.14
Sanserif Lower Case	0.63	0.50	0.68

*Significant at .05 level of Confidence.

One purpose of the study was to investigate which point size was better for legibility. Except in lower and upper cases of Cheltanham, legibility was better for bigger point size.

DISCUSSION

The study indicated that, on the whole, (except 12 point upper case of Roman) Cheltanham type face proved most legible. Roman proved superior to Sanserif. This finding could be supported by the results of Paterson and Tinker (1946). They found Cheltanham lower case better in the printing of Newspaper headlines. The superiority of upper case was substantiated by the investigation of Hodge (1962). He recommended the use of upper case in visual displays and lables. The finding that 12 point Roman was most legible was similar to that of Daftuar (1975, 1977). But at the present stage of our data it is difficult to explain the superiority of 10 point Cheltanham (both the cases) to 12 point. I suggest a more systematic and intensive study on this line to explore the possible causes.

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~~DA~~
DEVADAS R.P., EASWARAN P. (1972) Nutrient intake of selected vulnerable groups in COIMBATORE district in VORSTER D.J.M. The human biology of environmental change I.B.P. pub LONDON p 60 62

Very good description of food intake by children, expectant and nursing mothers related to recommendation of I.C.M.R for vegetarians and non vegetarians.

The intake of protective food is negligible.

"It is well known that the major cause of malnutrition is poverty. There are equally important contributing factors, however, such as lack of knowledge, defective personal hygiene, faulty feeding habits, rigid customs, taboos and traditions."

COIMBATORE est une ville importante au centre de la partie du DECCAN.

Nutrient Intake of Selected Vulnerable Groups in Coimbatore District

Rajammal P. Devadas and Parvathi P. Easwaran

Sri Avinashilingam Home Science College, Coimbatore, India.

Malnutrition, which is still widely prevalent, in spite of the great strides in recent years in the production of food (2) is a matter of great concern of nutritionists all over the world. About half of the people who inhabit the world are inadequately fed. For them there is too little food to lead a healthy life (14). Freedom from hunger is the cry of the day in the developing world(3).

Surveys conducted by the WHO and FAO reveal that malnutrition in the developing countries of the world is due to inadequate resources and failure to use the available resources to maximum advantage, and to the rapidly expanding population. Vulnerable groups, are children and expectant and nursing mothers, who are particularly affected adversely by malnutrition.

It is well known that the major cause of malnutrition is poverty. There are other equally important contributing factors, however, such as lack of knowledge, defective personal hygiene, faulty feeding habits, rigid customs, taboos and traditions(3).

Infants and children suffer malnutrition through improper and inadequate weaning foods. Women of child-bearing age are also susceptible to malnutrition because of the frequent occurrences of pregnancy and lactation which deplete the storage of nutrients in the maternal organism. Consequently, the morbidity and mortality rates are very high.

Dietary surveys conducted in various parts of India indicate that the meal patterns of the poor communities are basically similar, with an excessive cereal content, which provides nearly 80 per cent of the total food energy. The intake of protective foods is negligible (9, 17).

Quantitative data on the food and nutrient intake of these vulnerable sections of the population are scarce. The data obtained from the food consumption surveys conducted by the authors on the population from the poor socio-economic groups in the rural areas around Coimbatore are discussed in this paper. The method used was that decribed by the ICMR(10) involving weighing of both raw and cooked foods for a period of seven days. Thimmayamma and Hanumantha Rao (16) point out that weighing is the most reliable method.

Table I gives the food intake of the population compared with the allowances recommended by the ICMR (11).

The cereals commonly consumed by the vulnerable groups were rice, ragi and cholam. Among the pulses (split, dehusked legumes) redgram dhal and greengram dhal were used every day, while the whole grams were used occasionally and in season. Vegetables, locally available and of low cost such as brinjal, amaranth and onion and, among the fruits, banana, were ordinarily consumed by the rural families. Mutton was the flesh food eaten occasionally; all other flesh foods were considered too expensive. Milk was used in the form of butter milk. Whole milk, if at all used, was utilised in very small amounts in coffee or tea.

The diets of all the three groups surveyed were grossly deficient in all essential food values, the deficiency being greatest with regard to protective foods. The diets of the pre-school children did not contain the elements required to

TABLE 1. Mean Daily Food Intake of the Vulnerable Groups compared with the Recommendations of the ICMR (g)

Groups	No. of subjects	Cereals	Pulses	Leafy vegetables	Roots and Tubers	Other vegetables	Fruits	Milk & its products	Flesh foods	Fats and Oils	Sugar and Jaggery
Pre-school children	39	199	30	8	24	18	15	66	2	5	15
RDA Vegetarian		175	55	63	40 (Roots and Tubers + Other vegetables)		50	225	—	23	35
Non vegetarian		175	45	63	40 (Roots and Tubers + Other vegetables)		50	200	30	23	35
School going boys 6-12 years	48	322	32	12	34	13	4	67	10	11	9
RDA Vegetarian		285	70	88	63 (Roots and Tubers + Other vegetables)		50	250	—	30	50
Non vegetarian		285	60	88	63 (Roots and Tubers + Other vegetables)		50	200	30	30	50
School going girls 6-12 years	48	297	33	14	14	19	6	32	2	12	10
RDA Vegetarian		275	70	90	63 (Roots and Tubers + Other vegetables)		50	250	—	33	50
Non vegetarian		275	80	90	63 (Roots and Tubers + Other vegetables)		50	250	30	33	50
Expectant women	12	346	29	2	22	7	nil	20	14	4	3
RDA Vegetarian		400	70	150	75	75	30	325	—	40	40
Non vegetarian		400	55	150	75	75	30	225	30	40	40
Nursing Mothers	27	395	58	10	10	5	4	49	16	11	7
RDA Vegetarian		450	80	150	75	75	30	325	—	50	50
Non vegetarian		450	65	150	75	75	30	225	30	50	50

RDA = Recommended Daily Allowances

TABLE 2. Mean Daily Nutrient Intake of the Vulnerable Groups compared with the Allowances Recommended by ICMR.

Groups	No. of subjects	Calories	Protein (g)	Calcium (mg)	Iron (mg)	Vitamin A Retinol (mg)	Thiamin (mg)	Ascorbic Acid (mg)
Pre-school children	39							
Intake		952	25	312	21	204	0.84	10
RDA		1350	19	400-500	15-20	250	0.70	30-50
School going boys 6-12 years	48							
Intake		1430	38	629	36	281	1.53	8
RDA		1950	37	400-500	15-20	500	0.95	30-50
School going girls 6-12 years	48							
Intake		1314	33	548	35	325	1.66	8
RDA		1950	37	400-500	15-20	500	0.95	30-50
Expectant women	12							
Intake		1379	37	379	32	106	1.55	3
RDA		2500	55	1000	40	750	1.30	50
Nursing Mothers	27							
Intake		1736	48	568	37	257	1.88	12
RDA		2900	65	1000	30	1150	1.50	80

give a balanced diet, being adequate only in regard to cereals, roots, tubers and other vegetables. The consumption of cereals by school-going children, boys and girls, was also higher than ratios recommended by the ICMR.

That none of the expectant mothers was aware of the increased maternal requirement for food during pregnancy is evident from their diets, which were grossly inadequate in all food items, including cereals. Gopalan (8) observed in his surveys that the diets in pregnancy were not different from those during non-pregnant periods. This situation, of course, may well have been due to scarcity conditions.

Nursing mothers also consumed inadequate amounts of the right food items, the inadequacy being striking with regard to vegetables, fruits, milk and its products, and flesh food. These findings are in agreement with those of Gopalan *et al* (9).

The nutrient intake of the subjects was calculated for the raw—food equivalents, which were computed from the quantities of the cooked foods consumed by the selected subjects, using the figures given in the Food Composition Tables of Aykroyd *et al* (1).

Table 2 gives the nutrient intake of the vulnerable groups in comparison with the allowances recommended by the ICMR (11).

The diets of the pre-school children fell short of the recommended allowances for calories, calcium, vitamin A and ascorbic acid. Surprisingly enough, the protein intake was adequate, which probably may be due to the excessive intake of cereals and fairly good intake of pulses. The intake of iron was adequate, but how far it was utilised by the body is questionable, because the iron was mainly from vegetable sources. Due to the consumption of parboiled rice, the thiamine intake was also adequate. The mean daily nutrient intake of these children agrees with the previous studies conducted by Devadas and Easwaran(5), Narasinga Rao *et al* (12) and Devadas *et al* (6).

For school boys, the intake of calories, calcium, vitamin A and ascorbic acid was deficient, while the intake of protein, iron and thiamine was adequate. But the diets of school-girls did not furnish adequate amounts of all the nutrients except calcium, iron and thiamine, the inadequacy being striking with regard to calories and ascorbic acid.

There were large differences between the recommended allowances and the mean daily nutrient intake of expectant mothers with regard to all the nutrients except thiamine. In the case of iron, the inadequacy was of a smaller magnitude. Similar results have been recorded by Pasricha(13). Gopalan(8), and Shankar(15). The mean daily nutrient intake of nursing mothers was deficient in calories and all nutrients except iron and thiamine. This observation endorses the findings of Devadas and Mangalam(7).

CONCLUSION

The food and nutrient intake of the selected vulnerable groups is inadequate in many respects. In the diets of pre-school children, a lack of calories was noted. Nutrition, education and increase in the purchasing power of the families are required to improve the diets. The Applied Nutrition Programme needs to be planned, taking these findings into consideration.

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THE HUMAN BIOLOGY OF ENVIRONMENTAL CHANGE

PROCEEDINGS OF A CONFERENCE HELD IN BLANTYRE, MALAWI
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Ergonomics in agricultural engineering in India

INTRODUCTION OF ERGONOMICS TO INDUSTRY ? ??

p 528-529

India is a vast agricultural country having a Total cultivated area of about 139 million hectares. The human work force involved in agriculture is about 196. million. The annual food production is about 130 million tonnes. About 33% of the power used in agriculture comes from 80 million draft animals and the contribution of human power is 13%.

In India 70% of the farmers have holdings less than 2 ha Therefore various hand tools and manually operated equipments are extensively used for different crop production and processing operations. —

The general problems in the farm equipment design related to the field of ergonomics can be grouped under 5 heads

- Size and shape of handle. With a short handle, little production and fatigue. With long handled tools like rotary weeders it is much better
- Mode of operation: low lift water pumps, pedal operated paddy thresher have reciprocating mode of operation. The rotating mode is much more efficient. Maize sheller, winnower are hand operated it would be much better if pedal operated
- Physical work rate
  Normal young agricultural worker 35% of VO_2 max, 18 kJ/minute 110 beats/min
  Ploughing means walking 66 Km/ha, harrowing 20 Km/ha. A seat on wheeled tool bar is better
- Health Hazards due to vibration, noise and dust problems
- Safety: 1.000 physically handicaped a year only with threshers. Some research has been done one thresher feeding.

Studies on animal work system

EXCELLENT IDEA !!!

Animals particularly oxen are used in India as a major source of draft power. Studies in animal physiology to find proper work rest schedule for better animal performance are considered necessary.

Nice and precise little paper. I would like to know about the authors's work: Central Institute of agricultural engineering BHOPAL MADHYA PRADESH INDIA

ERGONOMICS IN AGRICULTURAL ENGINEERING IN INDIA

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India is a vast agricultural country having a total cultivated area of about 139 million hectares. The human work force involved in agriculture is about 196 millions. The traditional agriculture utilised mainly manual and animal power whereas the use of mechanical power has also come up in the recent past. The equipment for different agricultural operations and suitable for manual, animal as well as motor power are commercially available in the country. Often it is found that the human beings are not considered as a part of the system while designing the equipment, which deteriorates the systems performance. In this paper an attempt is made to identify the role of ergonomics in agricultural engineering with special reference to farm equipment design and operation.

India is a vast agricultural country having a total cultivated area of about 139 million hectares and the annual food production of about 130 million tonnes (1). About 33 percent of the power used in agriculture comes from 80 million draft animals and the contribution of human power is 13 percent which is available from a working force of 196 millions. The traditional agriculture utilised mainly these two types of powers i.e. manual and animal, but the use of mechanical power has also come up in the recent past. The agricultural equipment for different operations are commercially available in the country and many more have been developed in various research institutions. Often it is found that while developing the equipment, human being (operator) is not considered as a part of the system and therefore the man-machine system performance as a whole is poor.

In this paper an attempt is made to analyse the role of ergonomics in agricultural engineering in general and farm equipment design and use in particular.

In India, 70% of the farmers have holdings less than 2 hectares. Therefore, various hand tools and manually operated equipment are extensively used for different crop production and processing operations. Some of them are pickaxe, spade, seed dibbler, fertilizer broadcaster, seed fertilizer drills, paddy transplanter, hand hoe, hand cultivator, rotary weeder, wheel hoe, irrigation hand pump, sickle, maize sheller, groundnut stripper, paddy thresher, winnower, groundnut decorticator, chaff cutter etc.

The general problems in the farm equipment design related to the field of ergonomics can be grouped under following heads.

(1) Size and Shape of Handle:
Most of the traditional tools are short handled ones; which needs either squatting or bending posture for its operation. This induces undue strain on the operator and reduces the total output per day. For instance, the spade, a short handled traditional tool (Fig.1) had a capacity of 0.005 ha/h of weeding and interculture, but the actual output was 0.0023 ha/h (2). It was due to the reason that the operator had to take frequent rest to relieve the strain imposed on him due to posture. Long handled tools like rotary weeders (Fig.2) developed at some places cause less drudgery and perform better than the traditional tools. There is still further scope in improving these tools by providing the handles of proper size and shape based on ergonomic considerations.

In case of animal drawn equipment both, the height and the size of grip of handle as well as the length of lever are important. On shorter height the operator is compelled to bend more which induces unwanted strains in the back. In adverse condition the control of implement is quite difficult.

The anthropometric data on the agricultural workers can be of great help in proper design of handles and thus in reducing the operators' drudgery.

(2) Mode of Operation
A number of equipment like low lift water pump, pedal operated paddy

thresher etc. have reciprocating mode of operation. It has been proved that the rotary mode of operation is better than the reciprocating in terms of output as well as human comfort. Thus by changing the mode of operation from reciprocating to rotary type, the efficiency of the equipment can be increased.

Some equipment like maize sheller, winnower are hand operated. As it is well established that the leg muscles are stronger and can provide more power than hand muscles, such equipment can be made pedal operated for increasing the output and efficiency.

(3) Physical Workrate:
The acceptable work load for young Indian workers as found by Saha et al (3) is 35% of an individual's maximum aerobic power. The corresponding energy expenditure and heart rate would be around 18.0 KJ/minute and 110 beats/minute respectively. While designing the hand tools and manually operated equipment care should be taken to keep the operating efforts below this limit to attain the higher efficiency of the system.

In case of animal drawn equipment the operator has to walk considerably e.g. for ploughing 66 km/ha, for harrowing 20 km/ha in loose and difficult terrain. This induces heavy drudgery in operation. A number of wheeled tool bars have been developed on which a seat is provided for the operator. These tool bars are better in work output as well as human comfort. However, cost of these equipment is high which often prohibits its adoption by the small farmers.

(4) Health Hazards due to Vibration, Noise and Dust Problems:
At present India has about 400,000 tractors, 50,000 power tillers (two wheeled tractors) and 103,000 power operated knapsack sprayers. Vibrations of such machine pose a serious problem on the operator's health during various field operations. Noise and dust pollution cause a number of health hazards. A survey on the operators' health is very essential to have the clear picture of the situation.

(5) Safety:
In India, with the increase in use of tractors, power tillers, engines and other machines like threshers, the farm accidents have increased considerably. Specially thresher accidents have assumed a serious proportion, making annually about 1000 workers physically handicapped. Ergonomics has a very important role to play in the design of these equipment to make them safe for operators. Development of safe feeding chutes and automatic feeding mechanism for threshers have helped to some extent in minimising these hazards. The data on accidents due to various farm equipment (other than threshers) is necessary for selecting proper approach in solving such problems.

Studies on Animal Work System:
As mentioned earlier, animals particularly oxen are used in India as a major source of draft power. Studies in animal physiology to find out proper work rest schedule for better animal performance are considered necessary.

From the above discussion, it is clear that ergonomics has a very important role to play in improvement of agricultural equipment for better performance as well as more human comfort.

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~~A pilot study~~

A pilot study on traffic signs and signalling systems in BOMBAY.

A fully occidental old fashioned (british) experimental view without anything about INDIA. He doesn't quote DAFTUAR (1975) who is 10 times better

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Notes by WISNER June 86

on YOGI's document